Adaptive Management Framework for the California Water Fix and Current Biological Opinions on the coordinated operations of the Central Valley and State Water Projects

Contents

1 Executive Summary

Adaptive management is a science-based, flexible approach to resource management decision-making. When correctly designed and executed, adaptive management programs provide the ability to make and implement decisions while simultaneously conducting research to reduce the ecological uncertainty of a decision's outcome. These characteristics facilitate a management regime that is transparent, collaborative, and responsive to changes in scientific understanding.

The Delta Reform Act of 2009 identified adaptive management as the desired approach to reduce the ecological uncertainty associated with the management of the Sacramento-San Joaquin Delta system. The Federal and State water operations agencies (Bureau of Reclamation and Department of Water Resources) and the State and Federal fisheries agencies (U.S. Fish and Wildlife Service, National Marine Fisheries Service and the California Department of Fish and Wildlife) (collectively the 'Five Agencies') agree that adaptive management is the approach best suited to improve the management of the Delta and its resources.

Together, the Five Agencies commit to ongoing adaptive management under the current Biological Opinions of the combined operations of the Central Valley Project and State Water Project, as well as the effects of future operations under California WaterFix (CWF). This document sets forth the Adaptive Management Framework by which the Five Agencies will operate to reduce uncertainty and improve the performance of Central Valley water operations under the current Biological Opinions and CWF. This document also seeks to further highlight significant new investments in related research, monitoring and modeling needed to support this management effort, while explaining how each (existing efforts and new) will build on each other.

The Five Agencies' proposed Adaptive Management Framework includes a structured decision-making process with four overarching phases: (1) Plan; (2) Assess; (3) Integrate; and (4) Adapt.

- During **Phase 1: Plan**, initial operation and research priorities are set through the respective Operational criteria established through the BiOps, CESA authorizations and Bay Delta Water Quality Control Plan and Science plans. The operations criteria set water supply expectations while the science plans address how uncertainties associated with the operational and stressors affecting covered species will be addressed. The Science Plan will be developed collaboratively using the CSAMP/CAMT process. The Science to be conducted to address uncertainties will undergo independent review coordinated by the Delta Science Program.
- Through **Phase 2: Assess**, the products developed through the Science plan and the subsequent synthesis will undergo independent review, and the outcomes of this research will provide the basis for future proposals for management adjustments developed during Phase 3.
- In **Phase 3: Integrate**, interagency and agency-stakeholder discussions (based on the results of Phase 2's scientific assessments) will inform development of management adjustment proposals and additional research alternatives through a structured decision-making process. This 'scoping' process will also lead to the development of additional adaptive management questions to continue to address covered species and operational needs, assess benefits and identify uncertainty.

- The decision regarding whether to adopt or reject a management adjustment proposal lies with the Five Agencies and occurs during **Phase 4: Adapt**. Dependent on whether the proposed modification is considered within the adaptive limits of operations, changes to the operations criteria established through the BiOps, CESA authorizations and Bay Delta Water Quality Control Plan and Science plans may require reinitiation of consultation or permit amendment.

Additional groups may be needed to support the decision-making process by the Five Agencies and otherwise fulfill all aspects of this adaptive management program. One such group, the Interagency Implementation and Coordination Group (IICG), is currently being developed as a coordination body, co-led by Reclamation and DWR. Members of the IICG would include a senior manager/biologist from each of the Five Agencies, as well as from San Luis and Delta Mendota Water Authority and the State Water Contractors. The IICG will have a central role in implementing this framework, serving as a management hub that will provide input and assistance throughout the adaptive management process.

Success of the adaptive management process outlined within this Framework hinges upon significant new investments in related research, monitoring and modeling that build on existing efforts. These investments will address key uncertainties related to water operations and threatened and endangered species that have been raised in a number of different venues (e.g., the IEP Management, Analysis, and Synthesis Team and Salmon and Sturgeon Assessment of Indicators by Lifestage and the CSAMP Salmon Scoping Team) as well as during the development of a Biological Assessment for CWF. The Five Agencies are committed to leveraging the expertise found in these different venues; filling critical data and information gaps in the areas of integrated monitoring and research, mechanistic studies and models, information synthesis, and data access.

Working through the collaborative process outlined in this Adaptive Management Framework, the Five Agencies commit to reach consensus on operational decisions to the maximum extent possible, while still retaining individual agency discretion to make decisions (as appropriate). To that end, the Five Agencies seek to use the flexibility provided by an adaptive management approach in a way that balances gaining knowledge to improve future management decisions with taking actions in the face of uncertainty and achieving the best near-term outcomes possible.

2 Introduction

"Adaptive Management" is defined in California Water Code, section 85052, as "a framework and flexible decision making process for ongoing knowledge acquisition, monitoring, and evaluation leading to continuous improvement in management planning and implementation of a project to achieve specified objectives." At its most basic level, adaptive management is a learning cycle and feedback loop whereby resource managers may simultaneously make management decisions while gathering further knowledge and information about a single resource or set of natural resources. Adaptive management is inherently collaborative, requiring "communication and transparency among all interest groups as well as a willingness to overcome the institutional barriers to collaborative decision-making," (Luoma *et al.* 2015). Starting with Holling (1978) and Walters and Hilborn (1978), a general framework for adaptive management has emerged as a structured decision-making process that incorporates uncertainty by recognizing there are different possible outcomes to management actions. Adaptive management then relies on flexible decision-making that is adjusted as outcomes from management actions and other events become better understood.

Defined objectives and clearly identified expectations of management outcomes are critical to the adaptive management process (Williams, 2011). Based on objectives (and allowing for uncertainty), resource managers can then develop hypotheses about potential resource responses to various management actions and implement the selected action(s), while collecting information to compare the outcomes expected to those observed (Williams *et al.* 2009). The goal of any adaptive management program is to incrementally reduce uncertainty and management risks by learning more about how the target resource responds to the management regime being evaluated. The challenge becomes how to use the flexibility provided by an adaptive management approach in a way that balances gaining knowledge to improve future management decisions with achieving the best near-term outcome possible (Allan and Stankey, 2009). In practice, the bigger challenge has been reaching general agreement among parties about management tactics and their efficacy.

3 Intent and Objectives

Through the Adaptive Management Framework described in this document, the Federal and State water operations agencies [Bureau of Reclamation (Reclamation) and Department of Water Resources (DWR)] and the State and Federal fisheries agencies [US Fish and Wildlife Service (USFWS), National Marine Fisheries Service (NMFS) and the California Department of Fish and Wildlife (DFW)] (collectively, the 'Five Agencies') are committing to the ongoing adaptive management of operation of the Central Valley Project (CVP) and State Water Project (SWP) including future implementation and operation of the California WaterFix (CWF). The CWF would modify the existing SWP, which is operated in coordination with the CVP, to construct and operate three new screened diversions in the north Delta. These new facilities would be operated in conjunction with the existing south Delta diversion facilities to reduce reliance on south Delta exports, improve operational flexibility, and increase water supply reliability. A robust application of ecological, social, and economic science to support decisions that affect the operations of the CVP and SWP, and to support achievement of the co-equal goals[1] described in the Delta Reform Act of 2009 is critical to achieving success under this Framework. More specifically, the intent of this Adaptive Management Framework is to:

1. Create an adaptive management plan for long-term operations of the CVP and SWP that is consistent with state and federal endangered species laws and the the co-equal goals of the Delta Reform Act.
2. Develop and implement a robust science program needed to implement the adaptive management plan.
3. Identify the key uncertainties about how Central Valley water operations and other management actions to benefit the species can be implemented to avoid jeopardy and meet other regulatory standards applicable to state and federally-listed fishes, including future effects associated with the CWF.
4. Describe the basic processes and governance principles that will be needed to ensure the application of best available scientific information to all aspects of decision-making on multiple time scales (*i.e.*, multi-year, annual planning/forecasting, and even real-time operations considered within the bounds of annual planning[2]).
5. Communicate and provide transparency to the broader community of state, federal and local agencies; universities; scientific investigators; public water agencies and nongovernment stakeholders on how existing operations and other management actions will be assessed, how new scientific investigations will be prioritized (and funded) and how the results of those investigations will be integrated into adaptive management decisions.

[1] The co-equal goals are to provide a more reliable water supply for California and to protect, restore and enhance the Delta ecosystem.

[2] As described in Section 5.2, below, the adaptive management and decision making processes described in this Framework are not applicable to real-time operations. However real-time operations are mentioned in this Framework to provide context.

6. Describe how the proposed adaptive management program can build on and support existing efforts of the Interagency Ecological Program (IEP), Collaborative Science and Adaptive Management Program (CSAMP), Delta Stewardship Council/Delta Science Program (DSP), and individual agency science initiatives.
7. Describe how management relevant science in the areas of a) integrated monitoring and research, b) studies and models, c) information synthesis, and d) data access will be augmented.

Detailed objectives associated with the application of this Adaptive Management Framework are included in *Appendix 1—Initial Objectives Derived From Current Biops/CESA* and CWF, and are adopted into this document as an initial set of objectives, subject to further refinement, against which performance of operational decisions (and other management actions) can be assessed.

4 Key Uncertainties

With regard to Central Valley water operations under the 2008 USFWS Formal Endangered Species Act Consultation on the Proposed Coordinated Operations of the CVP and SWP, and the 2009 NMFS Biological Opinion and Conference Opinion on the Long-term Operations of the CVP and SWP (current BiOps), there remain a number of key uncertainties associated with identifying biological response to management actions. These uncertainties have been raised in a number of different venues (e.g. IEP Management, Analysis, and Synthesis Team (MAST) & Salmon and Sturgeon Assessment of Indicators by Lifestage (SAIL), and CSAMP Salmon Scoping Team (SST)) as well as during the development of a Biological Assessment for CWF.

Through IEP, the MAST and SAIL reports provide recommendations to fill critical data and information gaps, enhance the existing monitoring network and improve quantitative modeling capability to support transparent decision-making. Key recommendations from the MAST report to address critical data and information gaps include:

- Study the toxicity of delta contaminants on the health and viability of Delta Smelt,
- Refine entrainment and transport estimates of all life stages of Delta Smelt to quantify their effect on overall population viability,
- Develop estimates of predation loss to quantify its effect on Delta Smelt viability,
- Develop tools to better evaluate and monitor Delta Smelt food availability and composition, and
- Research the control and suppression of harmful algal blooms.

The SAIL report reviews multiple qualitative, statistical, and numerical approaches and summarizes how they may be applied to improve the scientific understanding of how water operations decisions affect salmonids and sturgeon (IEP SAIL 2016). The SAIL report further illustrates how the existing Delta monitoring network can be leveraged with the inclusion of updated technologies to improve data collection and analysis. The following list from the SAIL report identifies five system-wide recommendations to enhance the existing monitoring network and enable information to be incorporated into salmonid and/or sturgeon lifestage models:

- Incorporate genetic information to identify individual runs of Chinook Salmon,
- Develop juvenile abundance estimates for salmonids and sturgeon,
- Collect data associated with different life history metrics at multiple life stages for salmonids and sturgeon,
- Expand, enhance, and integrate fish survival and water quality monitoring, and
- Collect fish condition data on salmonids and sturgeon.

The CSAMP SST also prepared a report on the key findings of historical research and monitoring efforts and provided a gap analysis of existing and missing data that are critical to our understanding of salmon and steelhead survival in the Delta in the context of hydrodynamic conditions and water exports. Like the SAIL report, the SST report, *Effects of Water Project Operations on Juvenile Salmonid Migration and Survival in the South Delta* (CSAMP SST 2016), recommends building on the current and substantial body of scientific understanding. This CSAMP SST report also highlights key information gaps, which, if filled would likely improve our ability to more effectively manage operations and hydrodynamics to increase survival of salmonids emigrating through the Delta. These information gaps include our understanding of the role of factors influencing salmonid survival through the Delta, the role of Delta conditions in salmonid fitness at the individual and population level, and opportunities to improve salmonid population abundance and viability through changes to Delta conditions and water project operations. The SST's report recommendations are broken into four categories of action:

- Continue existing survival studies, monitoring, and analysis of data
- Implement short-term actions to improve salvage facility operations
- Develop a long-term monitoring, research and adaptive management plan
- Implement the long-term monitoring, research and adaptive management plan

Collectively, these efforts and others have sought to assess the current state of Delta science and highlight opportunities to assess the value of taking or modifying certain actions, reduce environmental uncertainty, and inform future management actions and decisions. Key uncertainties exist in five focus areas (described further in appendices 2-6).

- Listed Fish Performance (*Appendix 2—Key Uncertainties and Potential Research Actions Relevant to Listed Fish Species*): This focus area includes monitoring and research to reduce uncertainties related to the movement, behavior and survival of fish listed as threatened or endangered under the Federal ESA or the CESA. This focus area also examines a suite of hydrodynamic effects in the North and South Delta; as well as the effects of fish screens, nonphysical barriers, and predator removals on listed species.
- Yolo Bypass (*Appendix 3—Key Uncertainties and Potential Research Actions Relevant to the 2009 NMFS Operations Biop RPA Elements for Yolo Bypass*): This focus area includes monitoring and research to reduce uncertainties related to the effects of fish passage barriers and managed inundation of the Yolo Bypass.
- Tidal Wetland Restoration (*Appendix 4—Key Uncertainties and Potential Research Actions Relevant to Tidal Wetland Restoration*): This focus area includes effectiveness monitoring and research to examine the ecological function of planned tidal wetland restoration. Many of these monitoring actions and research studies while performed at the scale of an individual restoration site will be conducted using consistent sampling techniques developed by the Tidal Wetland Monitoring Project Work Team of IEP and will have a regional focus.
- Riparian, Channel Margin & Floodplain Restoration (*Appendix 5—Key Uncertainties and Potential Research Actions Relevant to Channel Margin Restoration*): This focus area includes effectiveness monitoring and research studies examining floodplain, channel

margin, and riparian restoration projects intended to benefit listed terrestrial and fish species.

- Delta outflow (*Appendix 6–Delta Outflow*): This focus area will continue and expand existing research into the ecological mechanisms that are supported by Delta outflow in order to robustly support any future modifications to Delta outflow requirements.

5 Conceptual Framework: Decision Making, Process, Governance

Given the uncertainties involved in assessing the effects of water operations and restoration activities on listed species, it is the decision of the Five Agencies that the only practicable way forward is with a firm commitment and explicit plans to meet the co-equal Delta goals and to take management actions such that are not likely to jeopardize the continued existence of any endangered species or threatened species (or result in the destruction or adverse modification of critical habitat as provided under ESA section 7(a)(2)) and to ensure CESA authorization compliance as new scientific and operational information becomes available. The proposed approach outlined in this Adaptive Management Framework incorporates aspects of adaptive management that are both "active" (where managers and operations are pushed in a process of experimentation to explore the benefits, limits and response to management actions) and "passive" (which lacks explicit experimentation and is instead more an assessment of existing and future conditions and circumstances). Ultimately the approach used in this Adaptive Management Framework will proceed with an iterative development of management alternatives whereby managers will use a few contrasting scenarios to explore the uncertainty surrounding the future consequences of a management decision.

5.1 Decision-Making

This Adaptive Management Framework outlines a collaborative process that will be essential to the success of the overall adaptive management program for the ongoing operation of the CVP and SWP, including future implementation and operation of the CWF. Under the adaptive management program, new information gained during implementation will inform operational decisions within the ranges of criteria and effects analyzed in applicable BiOps and CESA authorizations. The Five Agencies commit to working through the collaborative process outlined in this Adaptive Management Framework to reach consensus on operational decisions and other management actions to the extent possible and to elevate any disputes over decisions to appropriate levels of officials for each agency. Each agency retains discretion to make decisions as appropriate within its authority after considering the available information and taking into account the input of relevant groups described in this document. If any operational decisions are not within the ranges of criteria and effects analyzed in applicable BiOps or CESA authorizations, Reclamation will reinitiate formal consultation under ESA section 7 and implementing regulations (50 CFR 402.16), if necessary, and/or DWR will commence a permit amendment process under California law, if necessary.

Additional efforts or groups may be needed to fulfill all aspects of this Adaptive Management Framework and support the decision-making process by the Five Agencies, especially those resulting from implementation of CWF. One such group is currently being developed as described below. Descriptions of other groups and how they will be involved in the various phases of this Framework may be found in *Appendix 7*–*Groups Involved In Each Phase of the Adaptive Management Framework.*

5.1.1 <u>Interagency Implementation and Coordination Group (IICG)</u>

This coordination body, co-led by Reclamation and DWR, will have a central role in implementing this Framework. Members of the IICG would include a senior manager/scientist from each of the Five Agencies, as well as from San Luis and Delta Mendota Water Authority (SLDMWA), and the State Water Contractors (SWC). Additional agency staff and/or consultants may also participate to provide technical assistance or other support. Specific responsibilities of the IICG are currently being developed; however, the body will serve as management hub that will provide input and assistance to the adaptive management process. For example, it would:

1. Support and fund research and monitoring activities developed through the CSAMP process.
2. Refer, develop, or solicit proposals through existing or new individuals or entities, the IEP, etc.
3. Refer management related actions or proposals as appropriate to Delta Science Program for review by an independent science panel.
4. Assure transparency consistent with the requirements of the Delta Plan.
5. Review funding commitments and any implementation issues relative to the regulatory requirements of the current BiOps, CWF and CESA authorizations and to priorities and recommendations from the Delta Science Program, Collaborative Adaptive Management Team (CAMT), or related adaptive management fora.
6. Identify and secure needed infrastructure and resources to support scientific activities/monitoring.
7. Review scientific information and recommend changes to monitoring schema and management actions to the appropriate agency.
8. Establish mechanisms for developing and implementing adaptive management changes (*e.g.*, identifying performance measures/triggers to assess progress/outcomes, providing venues for synthesis and evaluation of available information, peer review, and developing recommendations in the face of new/refined understanding).

5.2 Relationship of Adaptive Management to Real-Time Operations

Under the current BiOps, a "real-time operations" mechanism allows for adjustment of water operations, within established parameters, to respond in real time to changing conditions for the dual purposes of increasing fish protection when it is warranted and for increasing water exports within established bounds for fish protection (Figure 5-1). The adaptive management and decision-making processes described here do not apply to these real-time operations; where individual real-time operations decisions must be made on a daily, weekly or monthly time scale; because new research efforts cannot be developed and deployed in that same window of time. However, changes to operational criteria in the current BiOps and associated CESA and CWF authorizations may be changed over time through the adaptive management process based on new information as part of the annual review.

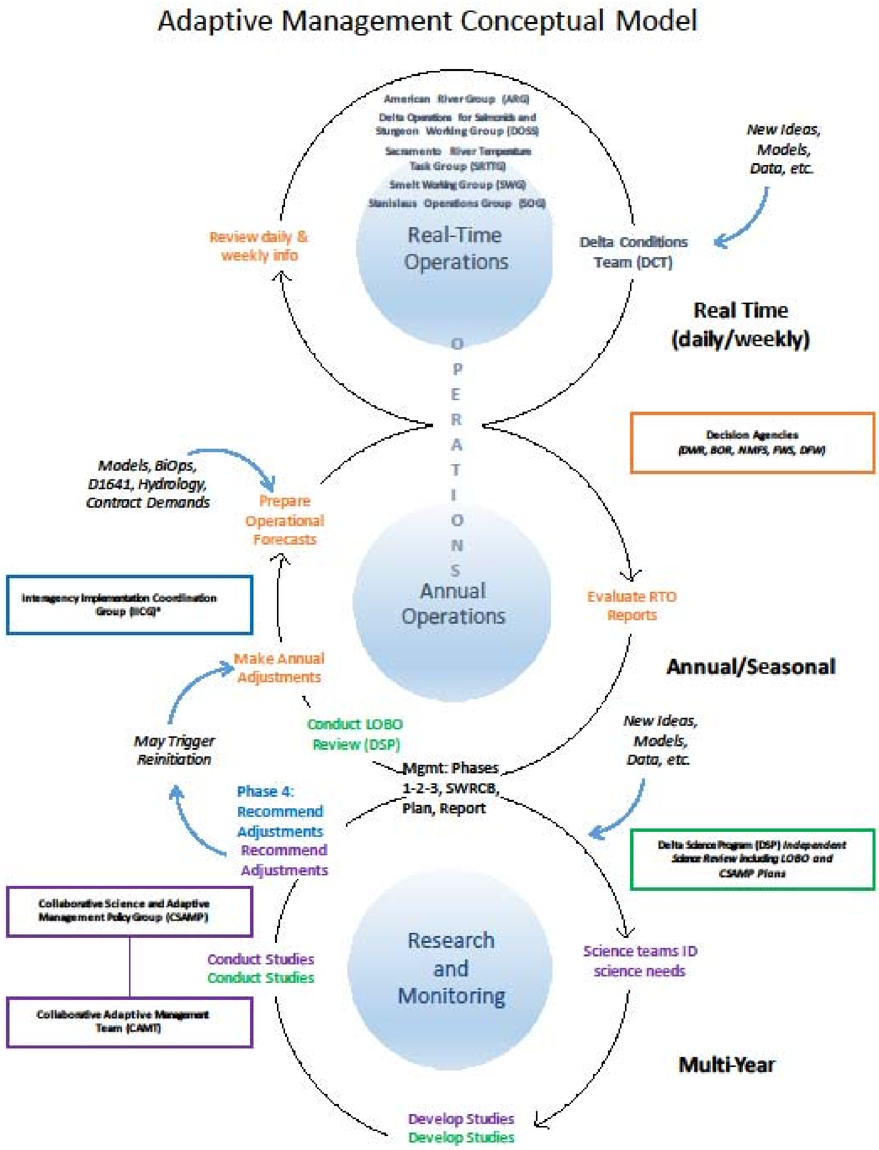

Figure 5-1. Describing the multiple time-scales of adaptive management for the California Water Fix and current USFWS and NMFS Biological Opinions on the coordinated operations of the Central Valley and State Water Projects

5.3 Adaptive Management Response to Climate Change

Gradual long-term changes in sea level, watershed hydrology, precipitation, wind patterns, and air and water temperature are projected to occur due to climate change. These changes contribute to uncertainty related to the factors affecting native species, water project operations and ecological responses. Because of this, climate change projections will be incorporated into management and science plans. Implementation of this Framework requires monitoring of climate change effects and projections, taking management actions, and adjusting water operations, research and monitoring in response as needed. Such adaptive management responses may include, for instance, identifying alternative locations for implementing restoration or habitat protection actions to increase habitat availability and suitability, increase productivity of the food web, better manage predators and invasive species, or to allow species movement across environmental gradients. Adjustments to water operations associated with inflow, outflow and exports is another example of potential adaptive responses.

Incorporating projected climate trends and year to year variability into the operational decision making process will initially be based on downscaled results of near-term (5 years) and long-term (25 years) Coupled Model Intercomparison Project, Phase 3 (CMIP3) and Phase 5 (CMIP5) climate and hydrology projections[3]. The Five Agencies will identify and implement, to the extent reasonable and practicable, measures to mitigate effects of the CVP, SWP, and CWF while considering the adverse effects of climate change to both species and the operational environment, and the ability to achieve the co-equal goals. The effectiveness of any remedial measures to reduce and/or control adverse effects of climate change will be monitored over time and, based on their efficacy, such measures may be adjusted through this Framework.

5.4 Adaptive Management Framework

This Adaptive Management Framework is modeled after the adaptive management approach used in the Comprehensive Everglades Restoration Plan (CERP 2006) which describes the inter-relationship between the identification of uncertainties, development of management questions, objectives, management alternatives, monitoring and research design, synthesis and decision making. Again, under this Framework, adaptive management changes to operations and other implementation actions would occur on an annual or longer (multi-year) basis, and are not intended to apply to real-time operations. This Adaptive Management Framework also includes specific elements described in the Delta Science Plan (DSP 2013) and recommendations from the Delta Independent Science Board (2016).

Four process diagrams, referred to here as "phases," illustrate the major components of the proposed adaptive management process: (1) Plan; (2) Assess; (3) Integrate; and (4) Adapt (Figure 5-X). The four diagrams (Figures 5-2 – 5-5) describe each phase of the process as well as how each phase relates to one another.

Certain analytical tools are useful during implementation of the phases of adaptive management, and are described below. Section 5.4.5 describes structured decision making and its utility in formulating research, monitoring and adaptive management actions at multiple scales, from the individual study up to overall program managament. Section 5.4.6 describes the use of

[3] http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/

conceptual models in adaptive management and provides examples of how such models are already in use to address ecological questions in the Delta. Further evolution of these models will be an integral part of the adaptive management process.

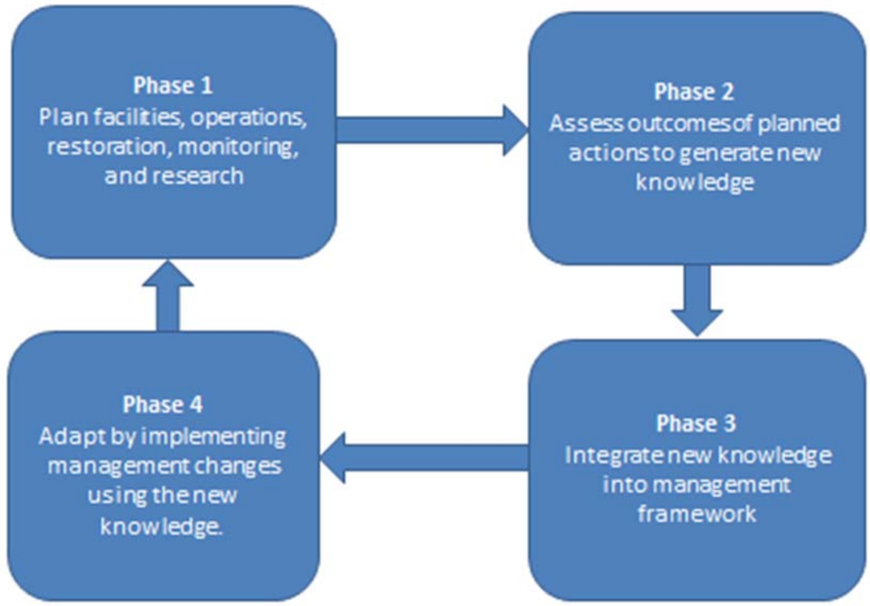

Figure 5-X. The four phases of the adaptive management process.

Phase 1: Plan

During Phase 1, initial operation and research priorities are set through the respective Operational criteria established through the BiOps, CESA authorizations and Bay Delta Water Quality Control Plan and Science plans. The operations criteria set water supply expectations while the science plans address how uncertainties associated with the operational and stressors affecting covered species will be addressed. The Science Plan will be developed collaboratively using the CSAMP/CAMT process. Changes to the Operations and Science Plans beyond year-1 could incorporate any management adjustments made in Phase 4: Adapt, that are based on the written proposals for management adjustment or the results of scientific study developed by the interagency and agency-stakeholder scoping process in Phase 3: Integrate. A diagram of the decision making process for effecting an adaptive management change under the Framework is described in Appendix 7.

One such adaptive management question in need of assessment is how effective are predator refugia areas around the NDD facilities? In this example, initial designs will be based on results and final recommendations from Preconstruction Study 3: Refugia Lab Study (Fish Facility Working Team, 2013). Change may be made based on modeling and assessment of original design prior to construction. Performance post-construction will require monitoring, and further assessment and will likely be an element of the CWF BiOp.

5.4.1 Phase 1: Plan

Define the bounds of the management problem and set management and research objectives.

As recommended in the 2016 Independent Science Board (ISB) report, an iterative learning cycle will be applied throughout the implementation of CVP and SWP water operations, associated habitat restoration actions, and other management actions. This includes activities related to design and management of new water diversion facilities as part of CWF, CVP and SWP operating criteria, any associated mitigation, and the design and implementation of monitoring and research programs to address efficacy of other major management strategies and topics of scientific disagreement. Successfully bounding ecological uncertainty with regard to management outcomes is critical and must include clearly defined problem statements or questions (and the objectives that will be used to inform decision points) and the means to address those questions (i.e., a sufficiently funded and staffed science and research program).

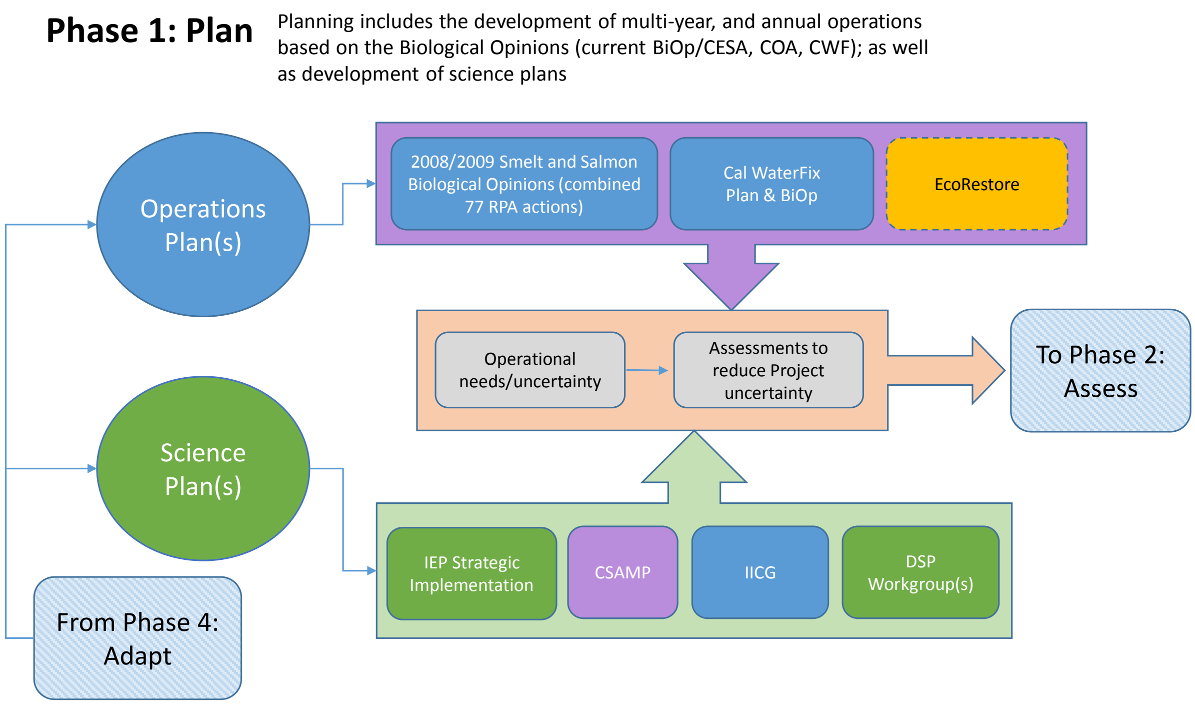

Figure 5-2 Phase 1, Plan: Facilities and operations, restoration/ecosystem management, and monitoring and research.

5.4.1.1 Design and Operations Planning in the Context of Endangered Species Act and CESA

5.4.1.1.1 Multi-year Planning:

The basic flow of the planning phase is shown in Figure 5-2. The CVP and SWP operate under the U.S. Army Corps of Engineers (USACE) flood control rules, State of California water quality standards, current BiOps and CESA authorizations, Memorandums of Understanding between Reclamation, DWR, and DFW, as well as other statutory and regulatory requirements. The current BiOps include some Reasonable and Prudent Alternative (RPA) elements intended to be implemented in an adaptive management framework. In addition, the operations planning completed to date for CWF involves substantial reliance on adaptive management.

The Five Agencies anticipate continuing to explore many of the questions and uncertainties related to the effects for the current Projects' operations on listed species and the efficacy of actions such as Old and Middle Rivers (OMR) flow restrictions, fall outflow and San Joaquin Inflow to Export requirements. Additionally, there will be new questions about the effects of the north Delta diversions (NDD) and their operation on out-migrating Sacramento River salmonids and green sturgeon, and possibly on Delta Smelt. Appendices 2 through 6 list key uncertainties identified in 2012 and 2013 within the development of materials for the Bay Delta Conservation Plan (BDCP)), components of which are now part of the CWF. This Adaptive Management Framework is also intended to address future research needs and is designed to answer these and other ecological and engineering questions through the process envisioned in Phase 2 (as shown in Figure 5-3).

5.4.1.1.2 Setting Objectives and Triggers:

While the current BiOps generally contain rationales and a sound conceptual foundation for individual actions, many actions do not explicitly contain measureable objectives needed for the design and planning of an adaptive management program. Species specific objectives included in *Appendix 1—Initial Objectives Derived From Current Biops/CESA and CWF* are adopted into the framework document as an initial set of objectives, against which performance of operations and other management actions can be assessed. These initial objectives are subject to further refinement as the process continues.

Given that adaptive management is intended to accommodate change both in the management of a resource and the corresponding response, objective triggers are an essential component of this Adaptive Management Framework to signal when an alternative management action may be warranted. Triggers are defined, pre-set and measurable conditions that prompt evaluation of information collected to that point in the context of current conditions and considering whether potential alternative approaches are warranted. For the purposes of this Adaptive Management Framework, triggers will be focused on longer term outcomes. Current BiOps specify (and the CWF biological opinion is expected to) specify, the amount or extent of incidental take that will trigger reinitiation of consultation as described within their respective incidental take statements. Reinitiation of ESA consultation is also required under 50 CFR 402.16 if the action (Central Valley water operation under the current BiOps and as stated in the CWF biological opinion) is subsequently modified in a manner that causes an effect to the listed species or critical habitat that had not been considered; if new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered; or if a new species is listed or critical habitat designated that may be affected by the identified action. CESA's regulations include amendment conditions and it is anticipated that the CWF CESA permit will include additional criteria that may trigger permit amendment.

Phase 2: Assess

Through **Phase 2: Assess**, identified operational needs and uncertainties are translated in a collaborative setting into research studies designed to reduce these uncertainties. Agency and stakeholder groups conducting research and modeling to answer adaptive management questions will vary depending on the logistics involved (e.g., major field studies will probably require the IEP). Annual operational decisions will be made using a few alternative scenarios to explore potential benefits and consequences and their relative uncertainty. Annual operating plans should identify potential opportunities to vary operations within the year in order to better meet the co-equal goals in the Delta while meeting regulatory requirements. Products pertinent to annual operations and assessments to reduce operational uncertainty will be peer-reviewed by independent review panels convened by the DSP. The review of these products will provide the basis for future management proposals developed during the scoping process of **Phase 3: Integrate**.

Continuing with the example of the NDD predator refugia; as part of the CWF RPM, the ability of the refugia to help salmon and other fishes successfully pass fish screens will be monitored and assessed. If the assessment includes a major field study component, the IEP will have a role in designing and implementing said study to assess

5.4.2 Phase 2: Assess

Represent existing scientific understanding through current operational decisions while continuing to identify uncertainty and alternate hypotheses as a result of ongoing monitoring and research.

The 2015 ISB report, *Fishes and Flows in the Sacramento-San Joaquin Delta* (ISB 2015) recommended implementation of integrative scientific approaches grounded on management questions and focused on processes, drivers and predictions. The approach outlined in Figure 5-3 reflects the complexities of the ecological responses being examined by individual research projects and tracked by system-wide monitoring.

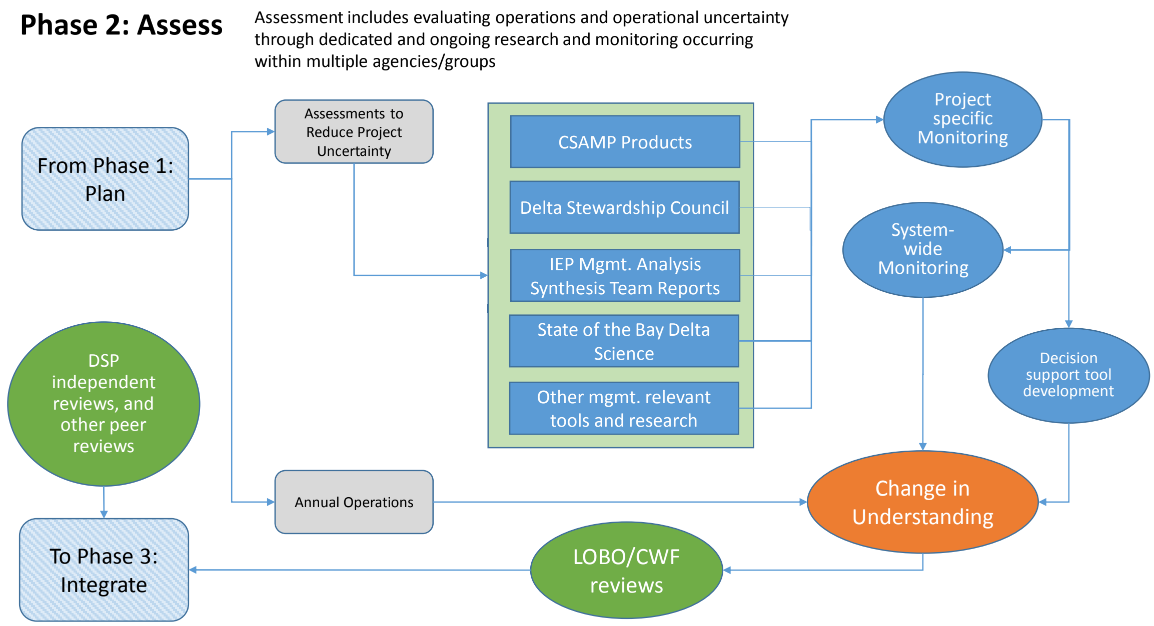

Figure 5-3. Phase 2, Assess: Collaborative Science, synthesis and performance assessment to inform management direction and change as uncertainty is addressed

An essential element of this Adaptive Management Framework, or any adaptive management process, is the development and execution of a scientifically rigorous research, monitoring and assessment program to provide a robust information base, as well as the synthesis of the resulting information to analyze and understand responses of the ecosystem to a particular management regime. This requires the implementation of an integrated core monitoring network for water operations that also incorporates many project specific monitoring actions (See Section 6: *Tools and Scientific Support*). The scientific and technical information generated from this comprehensive program will be organized to provide a process to assess progress against the triggers and objectives.

5.4.2.1 Annual Review

In order to ensure the realization of objectives of the current BiOps and CESA authorizations and those for the CWF and to support water supply reliability, periodic reviews of annual operations will be conducted as agreed on by the Five Agencies through consultation with the IICG. These reviews will be scheduled to occur in conjunction with the bi-annual Long-term Operations Biological Opinions Science Review (LOBO) review and will include an evaluation of operations using new and/or updated modeling, integrating the latest scientific, technical, and planning information (*i.e.*, Phase 3: Integration). This integrative adaptive management approach supports iterative improvement of system performance as learning and knowledge about the Delta and its tributaries improves. The Salmon Gap Analysis, Salmon Science Plan, Delta Smelt entrainment studies, Fall X2 studies, and Longfin Smelt flow abundance relationship studies, are all examples of studies from which new information regarding facility design, ecosystem restoration, other management actions, and annual operations may be evaluated. Based on the performance of models incorporating new information from those studies, it will be determined whether annual operations are meeting the requirements of the ESA and CESA. When appropriate, results of these evaluations will be used to inform proposed management alternatives within Phase 3 (Integrate) and the consideration of those alternatives in Phase 4 (Adapt).

Additionally, the DSP will at times be asked to provide technical review and assessments regarding ongoing and future research priorities, science plans, study designs, water operations, other management actions, or habitat restoration actions. Together these independent reviews, along with the research products from the many Delta science-related groups, will provide greater understanding to inform new management and research options as detailed in Phase 3 (Integrate).

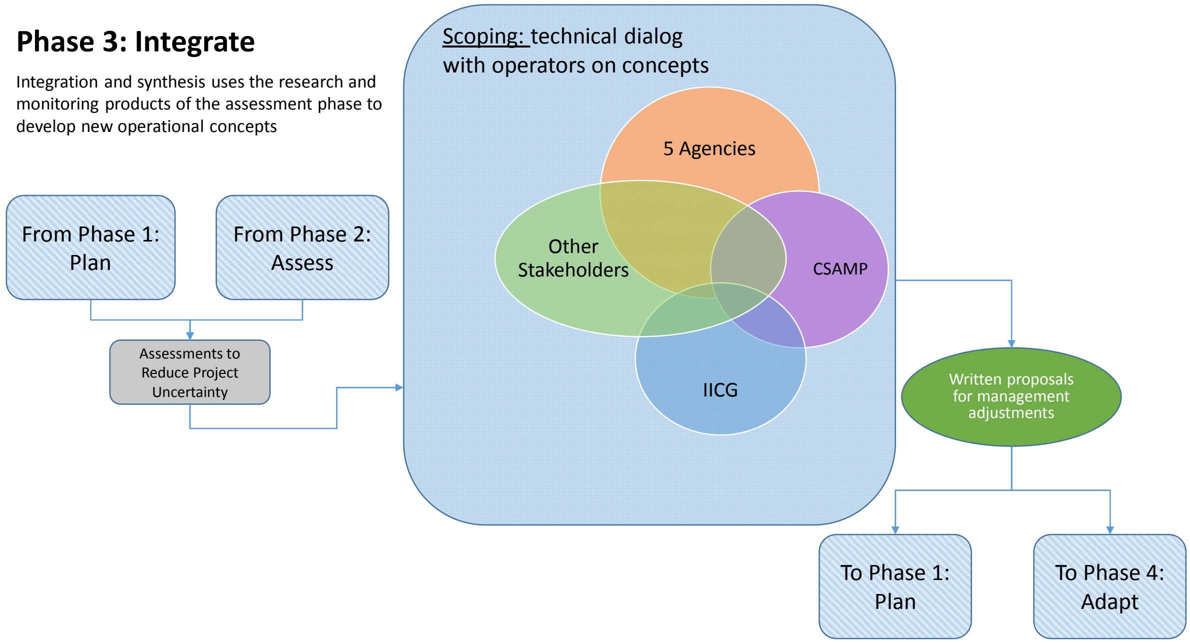

Figure 5-4. Phase 3, Integrate: Management and Science Integration

Phase 3: Integrate

The development of new executive level adaptive management questions to address operational needs and uncertainty occurs via several pathways and at multiple levels; these are generally described as scoping in **Phase 3: Integrate**. Through the structured decision making process, designed to test management strategies and data collection, interagency and agency-stakeholder discussions inform management and research alternatives based on the results of scientific assessments from **Phase 2: Assess**.

The results of both science products and their independent reviews are considered at multiple levels and at multiple venues including: between the Five Agencies, within CSAMP, and with the IICG. Determinations regarding whether the results of studies (e.g. monitoring post-construction performance of refugia areas) constitute a significant enough change in understanding to trigger changes to the management of the refugia or their monitoring and research will be made as part of a formal response to independent review and through the structured dialog of the scoping process. In this example, if the monitoring and research indicate that a management adjustment could improve the performance of the predator refugia, proposals to make said adjustment will be developed through the same scoping process.

5.4.3 Phase 3: Integrate

Reflect on outcomes and consider new approaches to management and research based on new understanding.

During the integration phase, which occurs on a continuing basis, the Five Agencies and participating stakeholders will develop recommendations for adaptive changes to management actions and, in some cases, may also recommend changes to monitoring and research approaches (Figure 5-4). In the development of these recommendations, the Five Agencies will engage stakeholders, academic scientists and other relevant groups through a scoping process to collaborate on the development of management actions and research projects stemming from Phase 2. The scoping process will use a structured decision making approach to address key uncertainties and otherwise maximize the transparency of decisions. Key structured decision making concepts include making decisions based on clearly articulated objectives, addressing uncertainties, and responding transparently to legal mandates and the public in decision making. Under this Framework, the CSAMP, in coordination with the IICG, is the venue in which to collaboratively define management relevant problems, establish objectives, define potential available alternatives, and clearly define the remaining uncertainty and research needs. The resulting proposals developed by these groups must be feasible, science-based and address identified problems and uncertainties. New knowledge revealing a potential opportunity to improve conditions or operations in the Delta and/or its tributaries could then lead to a change to CVP/SWP operations, other management actions, or another such adaptive management change in Phase 4 (Adapt).

Within Phase 3, the objective of scoping is to first determine whether information developed in Phase 2's assessment is significant enough to trigger consideration of changes to a management action or a monitoring and/or research program, and, if so, to determine the resources needed to implement the change. Scoping via structured decision making will involve operators and scientists from the Five Agencies with input from participating science and stakeholder groups. Through scoping dialogue, experts, stakeholders and agency managers seek to develop a common interpretation and understanding of the monitoring and research products. If, through structured decision making , it is determined that a change in a management action is appropriate, the group will then develop options or approaches to modify the management action to more effectively achieve its desired objectives.

The primary products envisioned for Phase 3 are written proposals for adjustment of management actions that will describe the anticipated effects of the recommended management change on listed species and water supply reliability and describe the actions necessary to implement said change. Following this Framework, these proposals will include input from stakeholders gained during the scoping process. Further, because the issues that trigger written proposals for management adjustments may have far-reaching effects, participation by Agency managers is a necessity during Phase 3, Peer review of proposed management actions and their scientific basis will be essential prior to making any decisions related to recommendations for a major management adjustment.

A critical element of Phase 3 will be to communicate the results of implemented actions, research, and monitoring to policy makers, managers, stakeholders, the scientific community, and the public, so that they can understand and evaluate progress toward addressing uncertainties and respond as necessary. With the guidance of the CSAMP, IEP, and the IICG the Five Agencies will prepare communications from time to time, as needed, and develop materials regarding adaptive management and monitoring matters for communication with a broader range of interests as part of the scoping process. The Five Agencies will ensure that study products are unbiased and explicitly and evenhandedly deal with uncertainty and disagreement in the analysis and interpretation, and that opposing points of view are clearly and evenhandedly presented in materials presented to stakeholders, external review bodies, and the public. To facilitate this understanding, the Five Agencies, with the assistance of the CSAMP process, IEP, and IICG will develop reports that serve the following purposes.

- Provide the necessary data and information to demonstrate that the current BiOps and CESA authorizations and those for the CWF being properly implemented.
- Identify the effect of current operations and those with CWF on covered species and the effectiveness of the conservation measures and mitigation.
- Disclose planned annual and long-term science priorities and programs and the synthesis of the information developed through the science program and there relevance to project operations and the requirements of the BiOps and CESA authorizations.
- Document actions taken under the adaptive management program (e.g., process, decisions, changes, results, or corrective actions).
- Disclose issues and challenges concerning implementation under current BiOps and CESA authorizations and those for the CWF and identify potential modifications or amendments that would increase the likelihood of success.

To demonstrate compliance with the co-equal goals in the Delta and the current BiOps, CESA authorizations and those for the CWF, an Annual Progress Report will be prepared by the Five Agencies. The highlights of the Annual Progress Report will be presented at a public workshop, presentations to the SWRCB, the DSC, DISB and DPIIC and the report will be made available to the public.

Phase 4: Adapt

The decision and final authority regarding whether to adopt or reject a management adjustment lies with the Five Agencies, and occurs during Phase 4: Adapt. Management decisions consider the proposals developed during Phase 3: Integrate and are based on the assessment and review of Phase 2: Assess. Depending on whether or not the proposed modification is considered within the adaptive limits of operations, changes to the operations criteria established through the BiOps, CESA authorizations and Bay Delta Water Quality Control Plan and Science plans may require reinitiation of consultation or permit amendment.

Using our refugia example, the Five Agencies will collectively consider proposals regarding any adjustment to management or monitoring and research related to predator refugia, to determine if the adjustment is within the flexibility of the existing RPA or new Reasonable and Prudent Measure (RPM). If a decision is made by the Five Agencies that changes the management or monitoring and research related to predator refugia that meets the criteria for reinitiation of consultation under 50 CFR 402.16, the Action Agency would request reinitiation of consultation with USFWS and/or NMFS and seek a permit amendment.

5.4.4 Phase 4: Adapt

Revise models and/or management actions based on information gained.

The fourth phase of this Adaptive Management Framework encompasses the decision to implement a management change through adjustments in water operations, restoration tactics, or monitoring and research support (Figure 5-5). The Five Agencies will use the written proposals and recommendations from Phase 3 to make management decisions based on their authorities. The actions encompassed within Phase 4 will occur under the direction of the senior management (Directors) of the Five Agencies, and in consultation with the SWRCB, Delta Stewardship Council, and consideration of input from stakeholders. At the conclusion of this process, decision-makers will decide whether or not to take the action proposed. The final decision will be consistent with the requirements of ESA, CESA, NEPA, the California Environmental Quality Act, Clean Water Act, Delta Plan, and the Bay Delta Water Quality Control Plan.

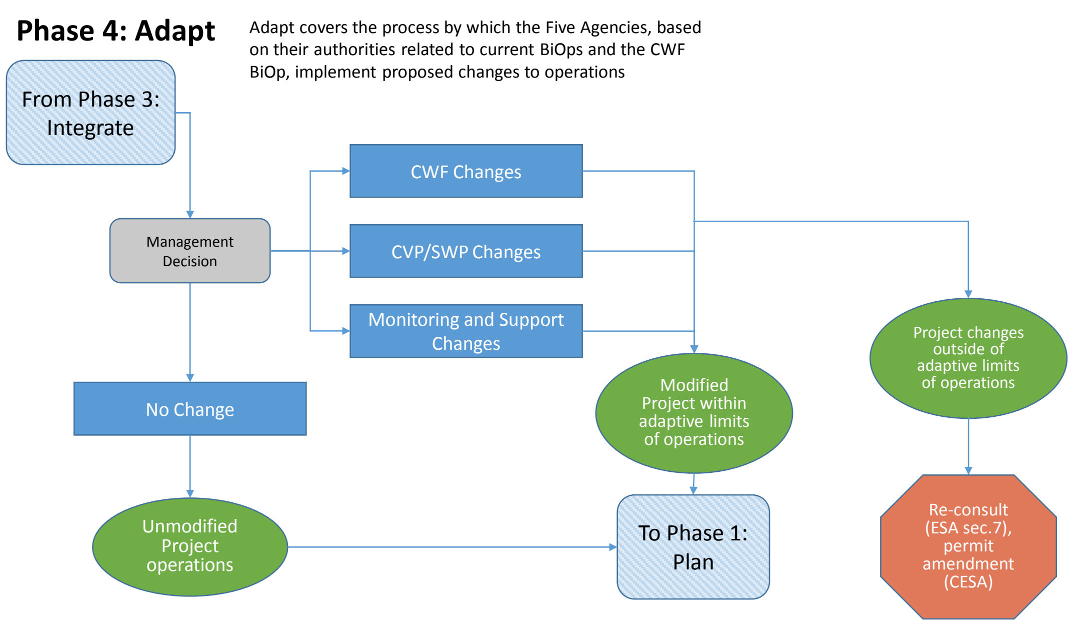

Figure 5-5. Phase 4, Adapt, Process for making an adaptive management change

5.4.5 Structured Decision Making

Structured decision making (SDM) is a general term used for a suite of analysis tools that can help achieve useful, robust decisions. The ESA Section 7 process itself is an example of an SDM process, with specified steps to assess the risk to species associated with a proposed action. Every decision consists of several primary elements: management objectives, decision options, and predictions of decision outcomes. By analyzing each component separately and thoughtfully within a comprehensive decision framework, it is possible to improve the quality of decision making. Existing Section 7 SDM processes and the table below are tools that may be used to implement all Phases of adaptive management. Ultimately, the uncertainties identified above and other questions that arise during the implementation of CVP and SWP operations, will be addressed in this adaptive management framework through the steps outlined in Table 1 below.

Table 1. Structured Decision Making

Step	Information to be Developed	Responsible Party(ies)
1. Define the problem	What specific decision has to be made? What is the spatial and temporal scope of the decision?	IICG, Five Agencies, other stakeholders
2. Define issues and objectives	What are the management objectives? Ideally, these are stated in quantitative terms that relate to metrics that can be measured. Setting objectives falls in the realm of policy, and should be informed by legal and regulatory mandates, as well as stakeholder viewpoints.	Five Agencies
3. Develop alternatives	What are the different management actions from which we can choose? This element requires explicit articulation of the alternatives available to the decision makers. The range of permissible options is often constrained by legal or political considerations, but structured assessment may lead to creative new alternatives.	IICG, Five Agencies, other stakeholders
a. Understand the uncertainty associated with each alternative	Because we rarely know precisely how management actions will affect natural systems, decisions are frequently made in the face of uncertainty. Uncertainty makes choosing among alternatives far more difficult. A good decision-making process will confront	Five Agencies

	uncertainty explicitly, and evaluate the likelihood of different outcomes and their possible consequences.	
b. Identify risk tolerance	Identifying the uncertainty that impedes decision-making, then analyzing the risk that uncertainty presents to management is an important step in making a sound decision. Understanding the level of risk a decision-maker is willing to accept, or the risk response determined by law or policy, will make the decision-making process more objectives-driven, transparent, and defensible.	Five Agencies
c. Identify linked decisions	Many important decisions are linked over time. The key to effectively addressing issues associated with linked decisions is to isolate and resolve the near-term issues while sequencing the collection of information needed for future decisions.	Five Agencies
4. Quantify the consequences of alternative management actions	What are the consequences of different management actions? To what degree would each alternative lead to successfully reaching a given objective? Depending on the information available or the quantification desired for a structured decision process, consequences may be modeled with highly scientific computer applications, or with personal judgment elicited carefully and transparently. Ideally, models are quantitative, but they need not be; what is most important is that they link actions to consequences.	Five Agencies
5. Understand the tradeoffs	If there are multiple objectives, how do they trade off with each other? Numerous tools are available to help determine the relative importance or weights among conflicting objectives; this information is used to compare alternatives across multiple attributes to find the 'best'	IICG, Five Agencies, other stakeholders

	solutions.	
6. Decide, take action, and monitor	For those decisions that are iterated over time, actions taken early on may provide a learning opportunity that improves management later. Decisions should be well-documented outcomes of steps 1-5 above.	Five Agencies

5.4.6 Conceptual Models

In the history of Delta ecosystem research, the term "conceptual model" has generally been used to refer to a process-based diagrammatic conceptual model that identifies sensitive resources and physical or biological processes that determine their state. An early example was the suite of models developed for the Delta Regional Ecosystem Restoration Implementation Plan (DRERIP), ca. 2008. An example dealing with factors affecting fish habitat is shown in Figure 5-6.

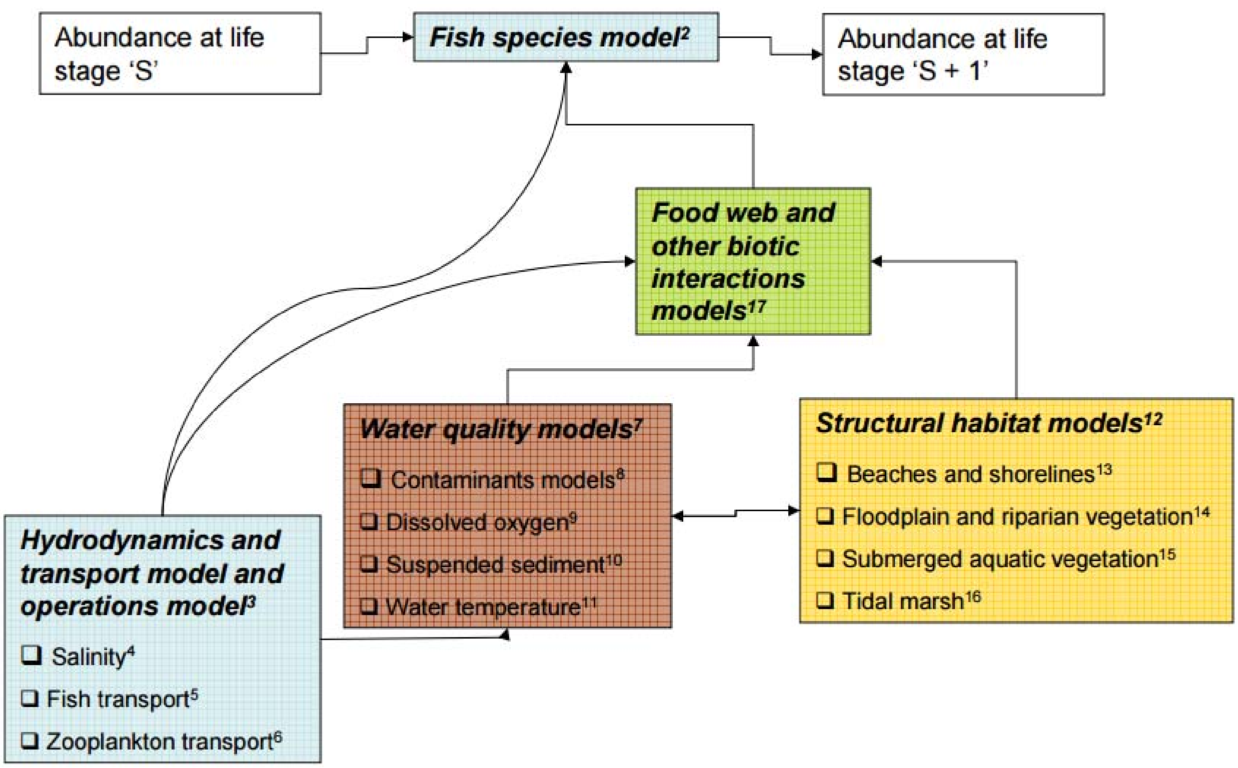

Figure 5-6. The Delta Aquatic Habitat Linkage Model of Nobriga (2008), an example DRERIP model.

Since this early example, there has been considerable development in the number and complexity of conceptual models being used to study Delta ecosystems. The 2015 annual report of the Collaborative Adaptive Management Team (CAMT 2015), for instance, refers to the use of conceptual models for the following:

- A life cycle model for winter-run salmonids in the south Delta

- A process model for Delta Smelt entrainment risk with reference to Old and Middle River flows
- An approach to aggregating study a suite of hydrodynamic, water quality, and particle tracking models, referred to collectively as an individual-based model (IBM), to identify adult Delta Smelt behaviors that best explain movement towards SWP and CVP, and entrainment.
- A re-evaluation of the re-examine life cycle model results of Maunder and Deriso (2011) using updated data sets and revised assumptions.
- Critically review the conceptual models that underlie adult Delta Smelt salvage and determine through multi-regression models the best suite of variables that explain historical salvage patterns.
- Use an existing life cycle model to understand the effects of entrainment on the Delta Smelt population.
- Perform a gap analysis evaluating the analytical tools currently in place to evaluate water project effects on salmonid survival.

These and similar efforts illustrate the utility of conceptual modeling tools to formalize understanding of how water operations affect fish, to assess the accuracy of these concepts in the context of information acquired through monitoring, research, and numerical modeling tools, and to formulate proposals to further test and improve the conceptual models. Foreseeable uses of conceptual models to assess California WaterFix include hypothesis development and testing regarding many aspects of the proposed action. Examples include the following.

- Fish movement into and through the redesigned Clifton Court Forebay, and means of minimizing incidental take associated with this.
- Entrainment, impingement, and predation in the intakes reach of the Sacramento River.
- Entrainment at the south Delta diversions and how it changes under dual operations.
- Effects of channel margin habitat restoration on salmonid predation, rearing, and passage through the affected channels.
- The effectiveness of real-time operations as a take minimization measure.
- Overall role of water operations with respect to fish population viability.

6 Research and Scientific Support

The current understanding of research needs that support adaptive management, has been developed based on a variety of sources. In assembling information regarding future research needs, the Five Agencies will rely as much as possible on peer-reviewed published literature. When such literature is not available, the Five Agencies will utilize agency reports that are available to the public (e.g., the MAST and SAIL reports). In some cases, the Five Agencies will also rely on information from reports or articles that have been submitted to scientific journals but that have not yet been accepted for publication. The below sections outline a commitment from the Five Agencies to invest in more robust tools, monitoring and research efforts to support this Adaptive Management Framework.

6.1 Delta Smelt Research and Understanding

Much of our current understanding of Delta Smelt is summarized in a synthesis report developed by the IEP MAST (IEP 2015). The MAST summary is structured around a conceptual model that includes a suite of hypotheses that outline the majority of the knowledge base for current Delta Smelt management efforts. The overall conceptual model is organized in a tiered structure and describes how Landscape, Drivers, and Habitat Attributes successively affect Delta Smelt survival, growth, health and reproduction. Moreover, more detailed models nested within the conceptual model describe how these factors are thought to affect individual Delta Smelt lifestages.

While the Delta Smelt MAST report reflects the significant progress of scientific understanding that has occurred over the past 20 years, the report also emphasized the need for additional monitoring, focused studies, and/or additional analysis and synthesis of existing data to better address a few unquantified, but often cited, sources of mortality. The biggest information gap may be the paucity of tools that attempt to quantitatively evaluate the impact of water operations on the Delta Smelt population in the context of other important ecosystem changes (e.g., habitat, prey and predators, contaminant loading, etc.). As noted in the Delta Smelt MAST report, filling these information gaps is critically important for improving management strategies for Delta Smelt and increasing their resiliency to foreseeable and unforeseeable future changes. Major areas where additional work is still needed include: 1) filling a few remaining critical data and information gaps; 2) improving modeling capability; and 3) applying numerical models in the adaptive management cycle. With respect to #1, the following list of remaining critical data and information gaps is organized around environmental drivers and habitat attributes identified in the MAST conceptual models.

Contaminants and Toxicity: There is a general awareness that exposure to contaminants can impair the health of Delta Smelt. A few studies have documented these adverse effects, but whether contaminants meaningfully impair the production and health of Delta Smelt (or their prey), or substantially limit their ability to compete with other fishes or avoid predators, is uncertain. Recommended studies include focused laboratory studies on metals, pesticides, pharmaceutical products, or mixtures of contaminants, as well as effects of nutrient loading on the food web, including phytoplankton and copepod growth.

Entrainment and Transport: Improved entrainment estimates will more accurately depict how entrainment affect key population attributes (e.g., population dynamics and viability). In order to avoid under- or over-estimating these effects, more precise estimates of entrainment losses of all life stages are needed.

Predation Risk: Predation is thought to be the largest source of mortality to Delta Smelt both historically and in the present. Important questions are how/if the rate at which predators remove Delta Smelt has changed, and how variations in various abiotic factors affect predator distribution and success. Key gaps include: 1) the distribution and diet of major predators – particularly Mississippi silversides (for larvae) and juvenile striped bass (for juveniles and adults) and 2) quantitative effects of environmental factors (turbidity, salinity, temperature, and hydrology) on the resulting distribution of predators and their predation rate on Delta Smelt.

Food: Poor feeding conditions can affect Delta smelt health and even increase the rate of predation on fishes; as such, food availability must be a critical aspect of Delta Smelt habitat that could be affected by several management actions. Critical data needs include:

1. tools that can be used to evaluate the impact of different invertebrate restoration strategies (e.g., tidal marsh, wastewater treatment, overbite clam control, suppressing competition from other fishes, etc.). The development of such tools would benefit from improved sampling of prey in under sampled regions (e.g., Cache Slough complex);
2. expansion of the four major surveys monitoring Delta Smelt (Spring Kodiak Trawl, 20 mm, Tow Net Survey, Fall Mid-Water Trawl) to more consistently sample prey;
3. studies of Delta Smelt growth (using otoliths) and feeding habits (using stomach contents) concurrent with zooplankton sampling; and
4. evaluation of the role of alternative prey, such as amphipods, in Delta Smelt diets.

Harmful Algal Blooms: High concentrations of harmful algal blooms (HABs) in the Delta may be having both direct (e.g. direct toxicity) and indirect effects (e.g. impacts to the Delta food web) to the Delta smelt population. Quantitative monitoring programs that collect data on HAB distribution and research on how to minimize adverse effects of these blooms, including through control and suppression, is needed.

6.2 Longfin Smelt Research and Understanding

Our current understanding of Longfin Smelt is summarized in the status review which supported the listing of the species as threatened under the California Endangered Species Act in 2009 (CDFW 2009). The survival of young Longfin Smelt may be influenced by mechanisms that stem from variation in Delta outflow, with peak survival for larvae that reared in the low-salinity zone (~2–4 psu; Hobbs et al. 2010). As a result, Longfin Smelt abundance is strongly affected by outflow; the effect of outflow on recruitment is believed to take place during the egg and larval stages, which occur during winter and spring (*Appendix 6–Delta Outflow*). However, the exact mechanisms driving the relationship between Longfin Smelt abundance and winter-spring outflow are unclear and is an active area of research.

Adult Longfin Smelt use a variety of Bay-Delta tributaries for spawning, including the Sacramento River, San Joaquin River, upper Suisun Marsh, the Napa River, and possibly a number of other smaller tributaries to San Pablo, Central and South Bays. The early juvenile life stages rear over a wide geographic area from the west Delta to San Pablo Bay and even into South Bay during wet years. There is uncertainty about the distribution of larval Longfin Smelt, because traditional surveys cover only a portion of the potential range. The only Bay Area tributary that is sampled is the Napa River. The fraction of the subadult Longfin Smelt population leaving and returning to the estuary is another key aspect of their biology that could use better quantification.

Longfin Smelt distribution in the north, east, and south Delta is influenced by water year type, with higher distributions occurring in these areas during dryer hydrologies. The life stages of Longfin Smelt affected by project operations are spawning adults, eggs, and larvae/small juveniles. Between June and October, the typical distribution of juvenile and adult Longfin Smelt is primarily in brackish water and coastal marine waters of San Pablo and San Francisco Bays downstream of the Delta and Suisun Bay. Longfin Smelt abundance within the Bay-Delta estuary has been highly variable, but generally declining since regular DFW surveys began. Recent Fall Mid-Water Trawl (FMWT) indices are very low compared to prior years.

Individual stressors affect Longfin Smelt at different times based on environmental conditions. Important threats and stressors to Longfin Smelt include reduced quality of rearing habitat; particularly, decreases in the availability of food, competition with and predation by nonnative species (e.g., competition with nonnative clams for food and predation on larvae), entrainment at water diversion facilities, and degrading water quality conditions (e.g., increasing temperatures and decreasing turbidity). Key scientific questions relative to Longfin Smelt are:

- the population effects of entrainment of adults and larvae in the south Delta,
- the mechanisms that support the well-documented January-June outflow abundance relationship, and
- the quantitative impact to food availability that can be made through restoration; for example, can it affect the abundance of Longfin Smelt?

Many of the research topics identified for Delta Smelt above apply to Longfin Smelt and should be developed to address both species.

Restoration of tidal wetlands and seasonally inundated floodplain under the current BiOps, Longfin 2081(b) and CESA consistency determinations, and EcoRestore are anticipated to increase primary and secondary productivity that may benefit Longfin Smelt in two major ways: an anticipated increase in copepod abundance and an indirect benefit to the extent that suitable food is exported downstream to rearing areas in the low-salinity zone. Restored intertidal wetlands also appear to provide spawning and rearing habitat.

During the past several decades, substantial changes in the species' composition and reductions in the abundance of the preferred food resources for larval, juvenile, and adult Longfin Smelt have been observed. The FMWT index for Longfin Smelt is positively correlated (in a multiple linear regression) with the previous spring's *Eurytemora affinis* (an important zooplankton prey organism for larval Longfin Smelt) abundance. The spring population abundance of *Eurytemora* has itself been positively correlated with outflow between March and May since the introduction of *Potamocorbula* (a small marine bivalve) as well as inversely correlated with mean ammonium concentrations and other variables affecting nutrient pollution in the low-salinity zone (Gilbert et al. 2011).

The role of total ammonia concentrations may be another factor affecting listed fish species by inhibiting primary productivity or altering the role of invasive species. The frequency, severity, and distribution of effects from total ammonia concentrations are the subject of ongoing research, but current science indicates a high likelihood that decreasing loading of total ammonia would have beneficial consequences for phytoplankton productivity and thus the productivity of the pelagic foodweb in and downstream of the Sacramento River.

A proposal focused on developing a conceptual model of Longfin Smelt life history based on current knowledge to support development or hypotheses regarding environmental drivers and life-stage specific vital rates (growth, survival etc.) that can be tested is currently being prepared for the IEP Scientific Management Team. Such an investigation should result in a synthesis useful for interpreting management relevant outcomes. The proposal will identify timelines and milestones, subject to change based on the actual magnitude of work and availability of resources to complete the work.

Current Longfin Smelt investigations resulting from settlement of litigation over the California Fish and Game Code Section 2081(b) permit for the SWP include:

1. Extension of the DFW Smelt Larva Survey (SLS) into Napa River. DFW is developing a means to generate an absolute abundance measures based on SLS sampling. This methodology can be used to generate estimates of regional contributions to Longfin Smelt hatch and rearing.
2. UC Davis is completing a second winter of sampling in lower estuary tributaries for Longfin Smelt larvae and adults (plankton and otter trawls) and has documented adult and larval use of Napa River, Napa Marsh (larvae only), Sonoma Creek, Petaluma River, Coyote Creek (large juveniles and adults only). UC Davis researchers also collected water from each of the tributaries and recently conducted otolith chemistry scans of otoliths from 2015 sampling conducted by both UC Davis and the DFW San Francisco Bay study. This information, combined with the otoliths, seeks to confirm that chemistry of rearing tributaries is "recorded." Otoliths from Bay Study LFS samples will be used to determine whether tributary contributions can be detected in older age groups (i.e., inferring successful reproduction).
3. Investigation into potential bias of the Fall Midwater Trawl. Investigations are also planned or underway to evaluate vertical and lateral distributions of Longfin Smelt and use of tidal marsh.

6.3 Salmonid and Sturgeon Research and Understanding

Water project facilities and their operations, coupled with other management actions (e.g., habitat restoration, fish passage, and harvest/hatchery management) have profound and complex effects on migratory fish and their habitats. There is high uncertainty in how native and migratory fishes will respond to these large changes in physical and biological conditions. Water exported from the north Delta with CWF infrastructure rather than south Delta will change the hydrology and hydrodynamics of the Delta. Operational flexibilities created by the new water project facilities may lead to system-wide shifts in water release strategies. Changes in both riverine hydrographs and Delta hydrodynamics will likely have a large influence on juvenile life stages of salmon, steelhead and sturgeon. Because few linkages between flows for these life stages have been studied, and future flow regimes may be novel, the expected response of anadromous fish populations to these changes is highly uncertain (Delta Independent Science Board, 2015).

What is certain is the needs for considerable attention placed on evaluating the direct and localized effects of building and operating a new water diversion facility in the north Delta on native and migratory fish. To that end, a robust monitoring plan is also needed to better understand how salmon, steelhead and sturgeon respond to changes in the physical and biological conditions at this particular location. Further, new water project facilities and changes to water operations in general and beyond CWF may have widespread effects that reverberate throughout the Delta and its tributaries.

Using the recommendations of the SAIL report and the CAMT SST report, we focus here on identifying long-term integrated core monitoring, research efforts, and synthesis tools that will be necessary to reduce uncertainties about how current and future water project operations impact migratory fish populations. The prioritized items below are not a comprehensive list of the science necessary for successful adaptive management. Rather, they are intended to highlight strategic system-wide science efforts that would benefit from integration into a broader management and regulatory context to facilitate funding security and consistency in implementation at the appropriate scales. Much of our most valuable monitoring and analytical tool development suffers from a lack of long-term funding security and fragmented implementation, which together lead to inefficiencies in applied science to better inform management decisions.

6.3.1 Integrated Scientific and Management Information System

Enhanced integrated core water quality and biological monitoring designed with adequate precision to support information needs on salmon, steelhead, and sturgeon abundance, movement, and/or survival at critical life stages linked to factors that have immediate effects on fishes' behavior and vital rates. Information needs more specifically include:

Quantify stock-specific juvenile salmon abundances

The current salmon monitoring network provides information on the presence and timing of salmon at various monitoring locations. However, more informative monitoring metrics, such as the abundance of individual salmon runs or populations, are required. Non-lethal genetic sampling coupled with new approaches to estimating trawl and seine efficiencies (e.g., paired coded wire tag and acoustic releases, multi-pass beach seining) can provide accurate information on stock-specific abundances of salmon at strategic locations of scientific and management value (e.g., Sacramento Trawl, Chipps Island, salvage, others). Specific guidance on how to implement this recommendation for juvenile salmonids is provided in the SAIL (IEP 2016).

Expand and integrate electronic tagging with water quality monitoring

A collaboratively designed and implemented expanded tagging program in the Sacramento River system would provide a better understanding of how water project operations influence Chinook salmon survival. This expanded tagging will require increased capacity for data management and capture-recapture modeling. The data generated from this program will build our understanding of how hydrologic variation, water project operations, habitat restoration and other management actions influence salmon survival. Real time monitoring of acoustic tags (in concert with representative tagging) will improve our understanding of where fish are in the system, potentially increasing operational flexibility and an increased ability to meet the Delta's co-equal goals.

Monitor and manage for life history diversity at multiple life stages

Maintenance and regeneration of life history diversity is central to salmon recovery plans and restoration actions, yet it is one of the most challenging metrics to monitor. Genetic, otolith, and passive integrated transponder (PIT) tagging tools will assist in the development of diversity indicators and insights into how to manage water project operations and restoration efforts to support life history diversity and long-term resilience. In order to inform management decisions for the protection of life history diversity, it would be valuable to enhance the current monitoring network with both parentage-based tagging (PBT) and otolith collection from adult spawners with funding and protocols for long-term archiving (i.e., the DFW Tissue Archive). Though relatively new, both of these technologies are well-tested, and would provide substantial management-relevant information. A complementary approach to assess the lifetime survival of the diversity of salmon outmigrants, many too small to acoustically tag, is to tag representative sizes of juveniles with PIT tags throughout the monitoring program to be sampled in downstream monitoring surveys or upon return in adult carcass surveys.

Develop Green Sturgeon dynamic rate functions and abundance

A number of key parameters regarding green sturgeon spawning distribution and indices of juvenile abundance are in need of further development. With significant improvement these parameters could be compared to environmental conditions to identify those conditions associated with green sturgeon production. Further developing an index of age-0 juvenile green sturgeon abundance; juvenile green sturgeon telemetry studies; run size and spawning distribution estimates; and quantitative modeling methods to generate estimates of life stage abundance and survival; will greatly improve our understanding of biology, habitat preference, and potential effects of large-scale projects and restoration actions on life stage. Specific guidance on how to implement this recommendation has been investigated and can be led by IEP affiliated scientists investigating sturgeon, and as identified in the SAIL (IEP 2016).

Develop marking/tagging program to identify all hatchery salmonids

To ensure our ability to estimate the proportion of natural origin fall-run and the impacts of hatchery practices on the viability of Central Valley fall-run Chinook salmon and ESA-listed stocks, we will need a long-term marking/tagging program of all hatchery salmonids and tag recoveries in the ocean and escapement surveys, as was recommended by the California Hatchery Scientific Review Group (2012). The ability to identify a hatchery fish allows greater flexibility to take actions similar to what is implemented through hatchery reform in the Pacific Northwest to minimize domestication or fitness reduction in salmonid populations (e.g., segregation weirs). A universal hatchery marking/tagging program would allow for focused research on understanding impacts of hatcheries on naturally-reproducing salmonid populations.

Implement steelhead monitoring plan to assess factors influencing anadromy

The status of the anadromous life history in natural *O. mykiss* remains largely unmonitored with current, extremely limited population trend data. This limitation can begin to be addressed by PIT tagging juvenile *O.mykiss* and quantifying river residency, response to temperature management, and the proportion that outmigrate and survive to adulthood as a means to determine whether management actions aimed at supporting the contribution of anadromy to the population are effective. DFW has developed a steelhead monitoring plan which is being implemented and will provide valuable data to initiate a systematic and deeper understanding of steelhead in the Central Valley. NMFS SWFSC has also been conducting genetic analyses of above-barrier hatchery broodstock and Central Valley floor populations of *O.mykiss* to better understand genetic structure and genes relevant to the expression of anadromy. These actions, combined with genetic analyses and acoustic tagging studies could provide valuable insights into the genetic and environmental factors favoring the different life history forms.

Update and centralize a seamless bathymetry and topography of the Central Valley watershed

Restoration in the Delta will likely have substantial effects on Delta hydrodynamics, perhaps even above water project operations. Thus, accurate bathymetry information as it relates to current conditions and future restoration planning will be increasingly necessary. Further, accurate biological modeling must be predicated on the accuracy of the physical channel morphology and bathymetry which drives hydrodynamics and floodplain inundation. Given that current measurements are outdated and datasets from different areas do not always align, it would be valuable to develop system-wide bathymetry and elevation data that is centrally available and covering the headwaters to the Bay, including the South Delta in particular.

6.3.2 Mechanistic Studies

Field, laboratory and modeling research that focuses on understanding mechanisms (e.g., habitat carrying capacities, disease, predation, food availability, contaminants) linking flow and temperature to different life stages of salmon is required. Specific studies include those that:

6.3.2.1 Assess impacts of predation

Salmon mortality varies across locations in a way that strongly suggests that predation by other fish is the proximate cause. Salmon survival also appears to have declined over time, concurrent with an increase in predatory fish such as large-mouth bass. Recent CAMT and SAIL technical teams working on south Delta salmonid survival and life cycle mechanisms, respectively, highlight that little is known about what ecological mechanisms are directly impacting salmon and sturgeon migration behavior and survival. These analyses and early modeling results indicate predation is non-random in the environment, happening mostly in a small percentage of a river system at "hotspots". From these data, predictive models can be developed to determine hotspot locations. These models require regional calibration, so surveys throughout the Delta as well as the Sacramento River basin will be needed.

6.3.2.2 Investigate salmon route selection and fish guidance technology

Landscape-scale survival studies suggest that the route a fish uses during outmigration strongly influences their survival to the ocean. Factors including distance to ocean, habitat quality, and predatory density, differ among routes and these differences affect overall salmon survival. Two-dimensional fish tracking suggests that routing of fish at channel junctions is determined by their position relative to a demarcation of flow divergence (i.e., the critical streak line). It is important to continue these studies of fish behavior at junctions and the extent to which engineering solutions can enhance fish survival/growth benefits. Current efforts evaluating the use of guidance structures to influence the proportion of fish diverted towards a higher survival route are underway. The CSAMP SST report suggested a broad suite of studies that may be needed to assess fish behavioral responses to various drivers (e.g., velocity, salinity gradients, tidal fluctuations, etc.) which will be important to adapt key operational parameters such as Old and Middle River flow (OMR) and the Inflow to Export ratio (I:E). Engineering solutions may also prove valuable depending on the extent to which the reach containing the NDD of CWF becomes a lower survival reach than alternative routes.

6.3.2.3 Implement restoration science and effectiveness monitoring

Focused research on how freshwater habitats influence salmonid size and timing of ocean entry and how this freshwater experience influences their overall ocean performance is needed. Floodplain and shallow water habitats, such as tidal marshes, and bays are not well-sampled by existing monitoring programs. Targeted studies are needed to examine the predicted benefits and risks of these habitats and the influence of associated restoration actions on Chinook salmon and sturgeon populations. Additionally, the benefits of restoration will likely be in fish quality (e.g., condition and growth), diversity in outmigration timing, and delayed survival benefits (e.g., ocean survival) rather than a potential direct increase in juvenile abundance in the freshwater.

6.3.3 Modeling and Synthesis

This category includes life-cycle models that integrate core monitoring and mechanistic study data to evaluate the influence of management actions (e.g., water operation, restoration, reintroductions, harvest, hatcheries, invasive species, climate change) into changes in the future viability of fish populations. Specific studies needed include those that:

6.3.3.1 Support system-wide physical models

Water project facilities and operations, by design, alter the timing and amounts of water flows, and thus water depth and velocities. The development and refinement of process-based model frameworks that track the movement of water and relevant constituents (e.g., heat, particles, contaminants, dissolved oxygen, etc.) throughout the entire Central Valley system would be very useful. The CSAMP SST report highlighted the need to update the Delta Simulation Model II (DSM2) as a critical step to better assessing the effect of Delta water operations.

6.3.3.2 Support system-wide ecosystem models

Biological models, coupled to physical models, are the basis for making the quantitative predictions required for effective adaptive management of anadromous fish and water resources. The development of process-based model frameworks to capture the fundamental biological processes (e.g., growth, survival, reproduction, evolution, movement, interactions with predators, competitors, prey, parasites, and pathogens, etc.) at each domain, and how the biotic components (e.g., prey, predators) move between domains. A variety of modeling frameworks should be developed and tailored to accommodate different management questions and biological endpoints.

6.3.3.3 Support salmon and sturgeon life cycle models

Develop a salmonid life cycle model tailored expressly to assist with evaluating salmonid responses to the long-term operations of the state and federal water projects as mandated by the courts and echoed by the Delta Science Program’s panel review (NMFS 2009; Rose et al, 2011). While significant progress has been made in the development, refinement, documentation, and implementation of the life cycle model (LCM) for winter-run Chinook salmon, the modification to water project infrastructure and operational decisions as part of CWF will continue to generate new information that can be used to further refine our understanding and the models.

6.3.3.4 Develop winter-run Chinook salmon ocean forecast model

Salmon populations are also highly responsive to changes in ocean conditions, which may obscure population responses to management if not accounted for. The development of an ocean forecast model will determine if ocean ecosystem metrics (coupled with stock-specific abundance estimates at ocean entry) can be used to forecast abundance of age 2 and 3 Sacramento River winter-run Chinook salmon in the mixed-stock fishery. Directly quantifying juvenile Chinook salmon in the coastal ocean is virtually impossible due to low population size, and yet understanding early ocean mortality may be the missing gap necessary to better evaluate how different sources of mortality impact the larger population of winter run.

6.3.3.5 Develop real-time salmon movement and survival model

The Delta Operations of Salmon and Sturgeon (DOSS) team uses multiple sources of information to infer the likely proportion of a stock that remains in the river vs. in the Delta during that stock's outmigration. The DOSS team provides managers with a weekly outlook regarding the vulnerability of ESA-listed stocks to Delta water project operations, yet this outlook is based on the judgement of experts and does not have a quantitative tool to assist in this evaluation and integration of information. The development of a statistical GIS movement and survival framework to process real-time salmon acoustic detections to better quantify salmon distribution and movement would further validate DOSS advice.

6.3.4 Data Access

Improved data availability, consolidation, and statistical support for real-time water project operations is critical, and key to this effort is data access.

The majority of biological monitoring data (except salmon escapement in Grandtab) is not readily available to the public or agency scientists. Staff members have to be contacted individually to acquire basic monitoring information which makes synthesis efforts challenging and laborious. In addition, identifying the point of contact for data can also be challenging. The development of a centralized accessible network for relevant physical and biological data necessary for management decisions related to salmon and water resource management would provide for more effective access and enhanced transparency.

7 Funding

As part of the current BiOps and CESA authorizations and the Bay Delta Water Quality Control Plan, a number of monitoring and research actions in the Delta are currently being implemented through the IEP and south Delta fish facilities management and enhancement efforts, as well as through the Fish Restoration Program Tidal Restoration Monitoring Program. IEP continuously reassesses its monitoring and research efforts to address management specific actions. Most recently, the SAIL has identified actions to improve tracking and real time decision support monitoring. Upstream monitoring on the Sacramento, Feather, American and Stanislaus rivers related to upstream reservoir management actions to protect listed fish species is also conducted. CSAMP has developed study plans and budgets for specific research efforts to address south Delta operational effects on salmon, Delta Smelt entrainment, and the Fall X2 action in the FWS 2009 OCAP BiOp. CSAMP is also developing study plans to address additional areas of scientific uncertainty related to operation of the SWP/CVP in the Delta. DFW as part of a settlement agreement with water agencies has created a Longfin Smelt technical team to address uncertainties related to current sampling approaches and how Longfin Smelt abundance is characterized, as discussed above this effort is expected to expand in the future.

Additional CWF scientific research and monitoring (identified in sections above) will be required to address the effects of water operations with North Delta Diversions in place, as well as questions related to the design and operation of the facilities themselves to minimize effects on listed species. During implementation of the current BiOps and CESA authorizations it has become apparent that additional resources for monitoring and research are need to address uncertainties and to provide better information upon which to base management decisions. Further, the additional work identified through the SAIL effort and the CSAMP Salmon Gap Analysis will need additional funding.

Current and anticipated funding requirements and timelines will be determined through Five Agency coordination and with the IICG.

8 Summary of Relationships to Other Programs

Important efforts are underway to implement science-based adaptive management to improve the scientific basis of operational decisions on annual or multi-year time scales. The Adaptive Management Framework will build on and augment the existing and planned efforts summarized below that are developing and implementing science to apply adaptive management principles to the Delta ecosystem. As the Adaptive Management Program is developed, specific linkage to each of these efforts will be defined.

8.1 Current Efforts

The original IEP studies of the influence of Delta flows on the recruitment of striped bass and the function of their supporting food web were an ambitious interagency attempts at an "adaptive management" program that pre-date the current definition of the phrase adaptive management (used in this Framework). In this context, the IEP program has expanded and morphed as agency priorities have evolved. As a result of this cooperative history, there are several very important efforts already underway to implement science-based decision support tools that seek to thereby improve the scientific basis of operational decisions at an annual or multi-year time scale (*Appendix 7–Groups Involved In Each Phase of the Adaptive Management Framework*).

To be most successful, this Adaptive Management Framework will build on and augment the existing efforts that have been developing and implementing science to apply adaptive management principles to the Delta ecosystem since the 1960s. In particular, this Framework will incorporate many elements of the process and structure of the IEP and the Collaborative Science and Adaptive Management Program/Collaborative Adaptive Management Team (CSAMP/CAMT), and the State and Federal Contractors Water Agency Science Program, and will continue to rely on the Delta Science Program for peer review and research support. Because these existing efforts will form core elements of this Framework, each effort is described below.

8.1.1 CSAMP

The CSAMP was launched following decisions by the United States District Court for the Eastern District of California to remand the current BiOps to the USFWS and NMFS for further consideration in accordance with the decisions (*San Luis & Delta-Mendota Water Authority v. Salazar*, 760 F.Supp.2d 855 (E.D. Cal. 2010); *Consolidated Salmonid Cases*, 791 F.Supp.2d 802 (E.D. Cal. 2011)), and more specifically following a decision by that court on April 9, 2013 (*In re Consolidated Delta Smelt Cases*, 2013 WL 1455592 (E.D. Cal. 2013) (2013 Court Order)). The 2013 Court Order was issued in response to a motion to extend the court-ordered remand schedule for completing revisions to the current BiOps and completing review under the National Environmental Policy Act (NEPA).

The 2013 Court Order allowed the parties making the motion (i.e., Reclamation, USFWS, NMFS, and DWR) additional time for the development of a proposed robust science and adaptive management program, with collaboration of the scientists and experts from the Public Water Agencies ('PWAs') and the non-governmental organization (NGO) community with the intent to inform the management actions incorporated into the current BiOps (and Reasonable and Prudent Alternatives) and consideration of alternative management actions.

The 2013 Court Order granted a one-year extension of time to deadlines associated with the cases' remand. The parties filed an annual progress report in February 2014, and the court granted a second one-year extension in March 2014. The parties prepared a second annual progress report in February 2015, requesting a third one-year extension. However, the Ninth Circuit Court of Appeals reversed the court's decisions that remanded the current BiOps to USFWS and NMFS (*San Luis & Delta-Mendota Water Authority v. Jewell*, 747 F.3d 581 (9th Cir. 2014), *cert. denied* 135 S.Ct. 950 (2015); *San Luis & Delta-Mendota Water Authority v. Locke*, 776 F.3d 971 (9th Cir. 2014)).

After reversal of the court's decisions requiring remand of the current BiOps, in 2015, all parties agreed to continue the CSAMP to promote the collaborative development of scientific information to inform sound decision-making in the future.

8.1.1.1 Organization

The CSAMP is structured as a four-tiered organization comprised of:

1. Policy Group consisting of agency directors and top-level executives from the entities that created CSAMP;
2. CAMT made up of managers and staff scientists that serve at the direction of the Policy Group;
3. Scoping Teams created on an as-needed basis to scope specific science studies; and
4. Investigators contracted to conduct studies.

8.1.1.2 Mission Statement

The CAMT mutually agreed on the following mission statement at its July 23, 2013 meeting:

> *The Collaborative Adaptive Management Team (CAMT) will work, with a sense of urgency, to develop a robust science and adaptive management program that will inform both the implementation of the current Biological Opinions, including interim operations; and the development of revised Biological Opinions.*

CAMT expects to revisit its mission statement (by increasing its scope) as it develops its Five Year Plan for CAMT. In the meantime, CAMT intends to remain focused on completing the studies initiated in 2014 and identify new initiatives based on the results of these studies.

Current products that are being developed by the CAMT scoping teams and principle investigators include analysis and synthesis tools and reports concerning Delta Smelt Entrainment, Gear Efficiency, Fall Habitat, and Salmonid survival. These reports from the two scoping teams will identify key findings, issues and recommendations for next steps. The next steps recommended in the two scoping teams' reports will be evaluated and prioritized by CAMT members. The highest prioritized efforts will be presented to the CAMT Policy Group and will be incorporated into the CAMT five year plan that CAMT is currently developing.

Items in the CAMT Five Year Plan may also support and contribute to advancing the objectives of other efforts including CWF and IEP. The CWF Five Agencies will ensure that efforts being implemented via CAMT or IEP are integrated and continue to move forward in those forums.

8.1.2 Interagency Ecological Program

The IEP has brought state and federal natural resource and regulatory agencies together to monitor and study ecological changes and processes in the Delta since 1972. The IEP currently consists of nine member entities: three state agencies (DWR, DFW, and the State Water Resources Control Board), six federal agencies (USFWS, Reclamation, USGS, USACE, NMFS, and U.S. Environmental Protection Agency), and two (current) partners: the San Francisco Estuary Institute and the Delta Science Program. These agencies and partners work together to develop a better understanding of the estuary′s ecology and the effects of the SWP/CVP operations on the physical, chemical, and biological conditions of the estuary. The 2014 IEP Strategic Plan describes IEP's goals and strategies to achieve them (http://www.water.ca.gov/iep/docs/IEP_Strategic_Plan102214.pdf).

8.1.2.1 Organization

The IEP is structured as a four-tiered organization comprised of:

1. Member agency directors;
2. IEP Coordinators made up of senior level managers who oversee the program
3. Science Management Team made up of managers and staff scientists that serve at the direction of the Coordinators to scope specific science studies. The IEP Lead Scientist provides strategic direction for, and oversight of, IEP science efforts, acts as the chief science advisor to the IEP Coordinators and Directors, chairs the Science Management Team, and serves as the primary scientific voice to all the groups;
4. Ad hoc project work teams that also develop scientific study concepts that can be recommended to the Science Management Team. The project work teams have included not only agency staff but have had extensive participation from academics and stakeholders; and
5. Investigators who are either agency staff or are academics or consultants contracted to conduct studies.

The IEP has coordinated Bay-Delta monitoring and research activities conducted by state and federal agencies and other science partners for over 40 years (*Appendix 7‒Groups Involved In Each Phase of the Adaptive Management Framework*). IEP monitoring activities are generally carried out to document CVP and SWP compliance with water rights decisions and California Endangered Species Act (CESA) authorizations and/or current BiOp conditions. Most of the monitoring under the IEP focuses on open-water areas and the major Delta waterways conveying water to the SWP/CVP facilities in the south Delta and downstream, including the entire Bay-Delta and portions of its watershed. The IEP produces publicly accessible data that include fish and invertebrate status and trends, water quality, estuarine hydrodynamics, and foodweb monitoring. Because of the history, size, and scope of this program's monitoring and research efforts in the Delta, it will continue to be a primary component in the implementation of CWF's adaptive management and monitoring program.

Although IEP member agencies have varying priorities, IEP provides a common ground for shared science priorities to come together and focus on supporting management needs for the Bay-Delta ecosystem and the water that flows through it. Some priorities are very explicit, such as monitoring specified in a permit or agreement. Others are focused on informing pending decisions or seeking new understandings that allow better decision making in water project operations or prevent new challenges such as invasive species.

Science Agenda

To meet anticipated science needs of the member agencies and provide the scientific tools and advice that resource managers can rely upon, the IEP has developed an IEP Science Agenda to focus on overarching management challenges anticipated in the next 3-5 years (http://www.water.ca.gov/iep/docs/2016_IEP_Science_Agenda_FINAL.pdf). The agenda serves as an outline for achieving important objectives by identifying and organizing science needs in the context of conceptual models, related information gaps and uncertainties, and strategies and priorities. The IEP Lead Scientist and IEP Coordinators have guided the development of the agenda, while drawing insights from the program scientists, project work teams, managers, and stakeholders particularly via the CSAMP.

8.1.3 Delta Stewardship Council, Delta Independent Science Board (DISB) and Delta Science Program (DSP)

Established by 2009 Delta Reform Act, the Delta Stewardship Council is charged with achieving the co-equal goals of providing a more reliable water supply for California and protecting, restoring, and enhancing the Delta ecosystem. The DISB provides a standing board of nationally or internationally prominent scientists with appropriate expertise to evaluate the broad range of scientific programs that support adaptive management of the Delta. The DISB will provide oversight of the scientific research, monitoring, and assessment programs that support adaptive management of the Delta through periodic reviews of each of those programs and reports to the Delta Stewardship Council. The Delta Science Program's mission is to provide the best possible unbiased scientific information to inform water and environmental decision making in the Bay-Delta region. The Delta Science Program's objectives are to:

- Initiate, evaluate and fund research that will fill critical gaps in the understanding of the current and changing Bay-Delta system.
- Facilitate analysis and synthesis of scientific information across disciplines.
- Promote and provide independent, scientific peer review of processes, plans, programs, and products.
- Coordinate with agencies to promote science-based adaptive management.
- Interpret and communicate scientific information to policy- and decision-makers, scientists, and the public.
- Foster activities that build the community of Delta science.

The Delta Science Program has particular expertise and experience organizing and facilitating independent scientific reviews. It also has primary responsibility for developing and implementing the Delta Science Plan. The Delta Science Program is expected to support CWF in the review of monitoring and research methods and results, and to provide technical support to the adaptive management process.

In its January 2016 review, *Improving Adaptive Management in the Sacramento-San Joaquin Delta*, the Delta Independent Science Board (ISB 2016) provided a number of insights regarding the way adaptive management has been applied to the Delta ecosystem as well as a number of recommendations for future implementation. Key findings and recommendations included:

- Agencies must become more actively engaged in collaborations;
- Adaptive Management must be identified as a high priority;
- Supporting Adaptive Management with dependable and flexible funding;
- Design and support monitoring to fit the magnitude of management actions and timing of ecosystem processes;
- Develop a framework for setting decision points or thresholds that would trigger a management response;
- Use restoration sites to test adaptive management and monitoring protocols.

The Delta Science Program has also identified a nine step adaptive management process. This Framework proposes to use a four phase approach to adaptive management which has been described in Section 5. Figure 8-1 describes how this Frameworks approach relates to the nine step process.

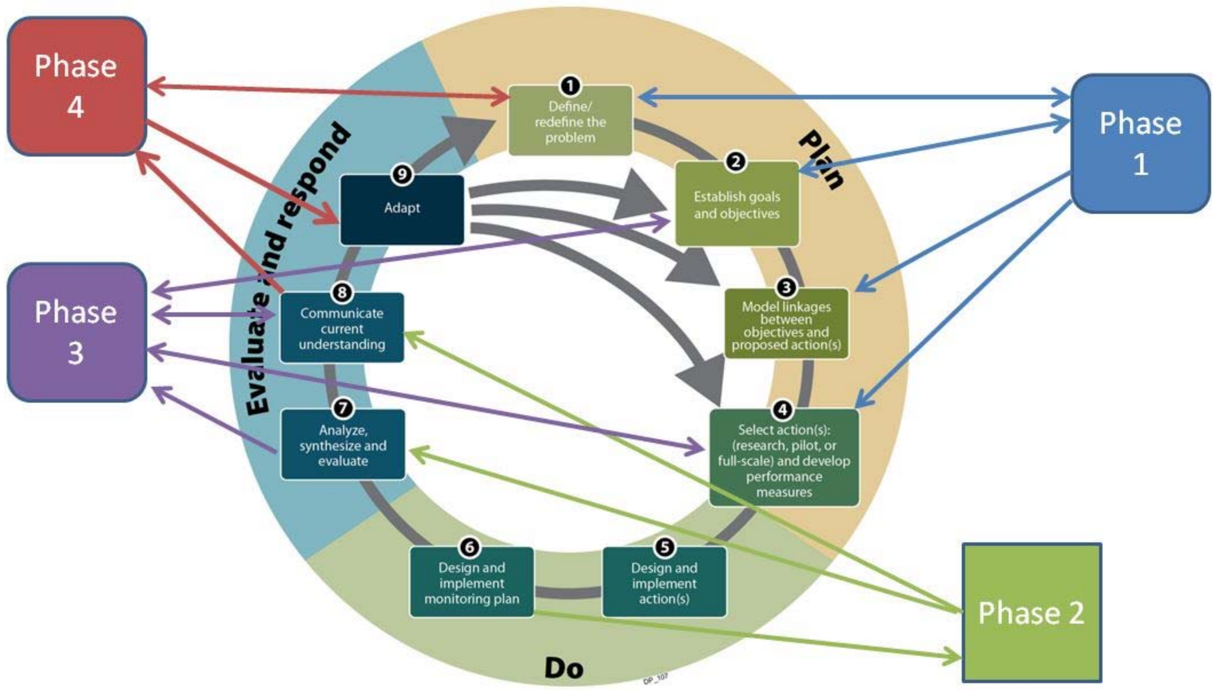

Figure 8-1. Describing the relationship between the DSP's nine step adaptive management process and the four phase process described in this Framework

Arrows "from" a phase means that particular step is contained within the phase, where arrows "to" a phase mean that that step influences a phase. Double arrows are both within and influencing the phase.

The overarching objective of the BiOps and CESA authorizations is to avoid jeopardy or adverse modification of critical habitat for the covered species. During Phase 1 the development of management actions to be tested via the science plans/priorities is similar to Step 4 and based on the problems defined by Step 1. In the development of management actions and science plans objectives (*i.e.* Step 2) will be clearly defined and modeled linkages of Step 3 will be created between proposed actions/studies and the objectives. Phase 1 results in the Operations plan and Science plan, as well as their implementation (*i.e.* Steps 5 & 6).

During Phase 2 the results of management actions and science plans implemented in Phase 1 are analyzed, synthesized and evaluated (Step 7); the results of which are communicated (Step 8) across agencies and stakeholders. Phase 3 then, develops the new understanding from Phase 2 products to advance a common understanding of those results (Step 8). Based on that understanding managers (agency staff, IICG, CSAMP) could redefine problem statements or develop new problem statements (Step 1) and establish new research or management objectives (Step 2) and recommend actions for management and or research (STEP 4). Ultimately during Phase 4, recommendations communicated from Phase 3 (Step 8) are adopted based on those recommendations (Step 9). If the recommendations would fall outside the analysis of the current BiOps and or CESA authorizations or those for CWF then the Action Agency would request reinitiation of consultation or seek a CESA permit amendment.

9 Reporting

Reports and plans will constitute the most visible documentation of the adaptive management process. In general, each adaptive management action will be proposed in a plan and its outcomes described in a report. Reports will take into account other existing processes and augment those efforts.

9.1 Annual Work Plan and Budget

On an annual basis, the IICG will prepare an Annual Work Plan and Budget for the upcoming year. The Work Plan will describe the proposed activities of the adaptive management and monitoring program. The Budget will set out projected expenditures and identify the sources of funding for those expenditures.

The IICG will submit the Annual Work Plan and Budget to the Five Agencies for review and approval. As part of this process, the Five Agencies will review the draft plan and provide written concurrence that the draft plan accurately sets forth and makes adequate provision for the implementation of the applicable permit terms under which the CVP and SWP operate. If any of the Five Agencies concludes that the draft plan does not do so, it will provide written notification to the IICG of the specific reasons for its conclusion. In such event, the IICG will modify the draft plan to the satisfaction of the Five Agencies.

A draft of the Annual Work Plan and Budget will be submitted for review and comments to the Five Agencies no later than 2 months prior to the release of the final Annual Work Plan and Budget. A final Annual Work Plan and Budget will be completed no later than 1 month prior to the beginning of the activities described therein.

At a minimum, the Annual Work Plan and Budget will contain the following information.

- A description of the planned actions under the adaptive management processes.
- A description of the planned monitoring actions and the entities that will implement those actions, based on the structured decision-making described below.
- A description of the anticipated research studies to be undertaken and the entities that will conduct the studies.
- A budget reflecting the costs of implementing the planned actions.
- A description of the sources of funds that will be used to support the budget.

9.2 Annual Progress Report

At the end of each implementation year, the The IICG will begin the preparation ofprepare an Annual Progress Report. The report will be based upon existing information, data, and analysis. The report will provide an overview of the IICG activities carried out during the previous implementation year and and provide information sufficient to demonstrate that the proposed action is being implemented consistent with the provisions of the Plan, the Implementing Agreement, and its operating criteria and the associated regulatory authorizations.

The IICG shall solicit input on the draft of the Annual Progress Report from the Five Agencies, and submit the report to the Five Agencies for review and approval. The IICF shall finalize and submit the Annual Progress Report to the Five Agencies for their acceptance within six months of the close of the reporting year.

The annual progress report will include, among other things, the following types of information.

- Documentation of the implementation of habitat restoration and protection measures specified in the Proposed Action in relation to their schedule and performance specifications, including the following components.
    - A summary of the habitat protection and restoration actions that have been initiated, are in progress, or have been completed, including information regarding the type, extent, and location of protected and restored habitat for listed species. The report will document these actions on an annual and cumulative basis.
    - The status of the protected and restored habitat and an assessment of the progress toward meeting all land acquisition goals for habitat protection and restoration. This will include details on compliance with restoration requirements.
    - A general summary of all land management activities undertaken on protected and restored habitat, including a description of the management issues associated with each habitat protection or restoration site.
    - Identification of actions that have not been implemented on schedule and an explanation for the deviation from schedule. For actions that are behind schedule, a suggested schedule or process for completing them will also be included.
- Descriptions of actions taken pursuant to the adaptive management programs.
    - Documentation of the results of monitoring and research actions prescribed in the PA or its authorizations as issued by the Five Agencies, or directed by the IICG. This is to include a summary of the actions that have been initiated, are in progress, or have been completed for each conservation measure, including information related to type, location, and method of implemented actions. The report will document this on an annual and cumulative basis.
    - Adaptive management decisions made during the reporting period, including the scientific rationale for the action.
    - Use of independent scientists or other experts in the adaptive management decision-making processes.
    - Changes in the manner in which conservation measures arethe proposed action is implemented, based on interpretation of monitoring results and research findings, or other information.
- An accounting of the funding provided to support the monitoring, research, and adaptive management programs. The accounting will identify the source of the funds, the annual and cumulative expenditures to support the programs by cost category, and any deviations in expenditures from the associated *Annual Workplan and Budget*.

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11 APPENDICES

Appendix 1—Initial Objectives Derived From Current Biops/CESA and CWF

Appendix 2—Key Uncertainties and Potential Research Actions Relevant to Listed Fish Species

Appendix 3—Key Uncertainties and Potential Research Actions Relevant to the 2009 NMFS Operations Biop RPA Elements for Yolo Bypass

Appendix 4–Key Uncertainties and Potential Research Actions Relevant to Tidal Wetland Restoration

Appendix 5–Key Uncertainties and Potential Research Actions Relevant to Channel Margin Restoration

Appendix 6–Delta Outflow

Appendix 7–Groups Involved In Each Phase of the Adaptive Management Framework

Appendix 1—Initial Objectives Derived From Current Biops/CESA and CWF

Objectives (Triggers for Adaptive Management action)	BiOp and CWF Focus Area addressed
Restore at least 8,000 acres of tidal brackish and freshwater emergent marsh and shallow sub-tidal habitat and transitional uplands in Suisun Marsh and Cache Slough to accommodate sea level rise and in the western Delta to improve aquatic primary productivity and habitat for listed and other native species.	Tidal Wetland Restoration
Restore 17,000 acres of floodplains (through Yolo Bypass Fishery Enhancement Plan Implementation) to improve adult and juvenile fish passage and to avoid and minimize effects on listed terrestrial species by providing a range of elevations that transition from frequently flooded (e.g., every 1 to 2 years) to infrequently flooded (e.g., every 10 years or more) areas. This restoration action will provide species with a range of habitat conditions, upland habitat values, and refugia during most flood events.	Listed Fish Performance; Yolo Bypass; Riparian, Channel Margin & Floodplain Restoration
Enhance 4.5 miles of channel margin in the Sacramento River system to provide habitat along important migratory routes for anadromous fish and to improve wildlife movement.	Riparian, Channel Margin & Floodplain Restoration
Promote connectivity between low-salinity zone habitats and upstream freshwater habitats and availability of spawning habitats for native pelagic fish species.	Tidal Wetland Restoration; Riparian, Channel Margin & Floodplain Restoration
Manage the distribution and abundance of nonnative predators in the Delta and tributaries to reduce predation on listed fishes.	Listed Fish Performance
Manage the distribution of listed fish species to minimize movements into areas of the Delta where predation risk is high.	Listed Fish Performance
Control invasive aquatic vegetation that adversely affects native fish habitat.	Listed Fish Performance; Tidal Wetland Restoration; Riparian, Channel Margin & Floodplain Restoration

Species-Specific Objectives	
Delta Smelt	
Limit entrainment mortality associated with operations of water facilities in the south Delta to ≤5% of the total Delta Smelt population, calculated as a 5-year running average of entrainment for subadults and adults in the fall and winter and for their progeny in the spring and summer. Assure that the proportional entrainment risk is evenly distributed over the adult migration and larval-juvenile rearing time-periods.	Listed Fish Performance
Achieve a Recovery Index ≥239 for Delta Smelt for at least 2 years of any consecutive 5-year period, measured from initial operations through the end of the permit term. The midpoint of any two consecutive Recovery Index values cannot be lower than 84.	Listed Fish Performance; Riparian, Channel Margin & Floodplain Restoration

Enhance extent of suitable habitat (as defined by flow, salinity, temperature, turbidity, food availability and presence of Delta Smelt) to support Delta Smelt in the Action Area by the achieving the following subobjectives: • Provide a monthly average of at least 37,000 acres of open-water habitat in hydrologically wet years[3], and at least 20,000 acres of connected open-water habitat in hydrologically above-normal years[4], of habitat surface area during July–November that is between 1 to 6 psu. This habitat will additionally meet all of the following criteria: extensive vertical circulation including gravitational circulation, contiguous with other open-water habitat, lateral mixing and other hydrodynamic processes keeping Secchi disk depths less than 0.5 meters, high calanoid copepod densities (over 7,000 per cubic meter), hydrologically connected to substantial tidal marsh areas, and maximum water temperatures less than 25°C. • Increase the extent of tidal wetlands of all types in the Action Area by 8,000 acres. In Suisun Marsh, West Delta and Cache Slough, individual restoration projects must show a net-positive flux of calanoid copepods and mysids from restored wetlands into open water occupied by Delta Smelt. Food production targets and export distances will be determined through field investigations and modeling and refined through adaptive management. • Increase by 100% the surface area of open-water, very low-salinity (<1 psu) habitat in the Cache Slough during July–November. This habitat will additionally meet all of the following criteria: extensive lateral mixing, contiguity with other open-water habitat, hydrodynamic processes keeping Secchi depth less than 0.5 meters, high calanoid copepod density (over 7,000 per cubic meter), and temperature criteria described above.	Listed Fish Performance; Tidal Wetland Restoration; Yolo Bypass; Riparian, Channel Margin & Floodplain Restoration

[4] Because July–November crosses a water year boundary, the water-year type criteria apply to the first three months of that period.

Longfin Smelt	
Achieve longfin smelt productivity, as measured by the Fall Midwater Trawl, equal to or greater than predicted for 5 of 10 years running based upon a regression of 1987 to 2000 longfin smelt abundance against December through May mean outflow (or X2).	Listed Fish Performance; Riparian, Channel Margin & Floodplain Restoration
Limit entrainment mortality associated with operation of water facilities to ≤5% of the longfin smelt population, calculated as a 5-year running average of entrainment for subadults and adults in the fall and winter and for their progeny in the winter and spring. Assure that the proportional entrainment risk is evenly distributed over the adult migration and larval-juvenile rearing periods.	Listed Fish Performance
Chinook Salmon, Sacramento River Winter-Run Evolutionarily Significant Unit	
For winter-run Chinook salmon, achieve through the CWF and other actions an interim 5-year geometric mean through-Delta survival objective of 52%. This survival metric is an interim value based on limited data from fall-run Chinook salmon in the Sacramento River. This survival metric will be revised to account for new monitoring data and improved modeling when available.	Listed Fish Performance
Create a viable alternate migratory path through Yolo Bypass in >70% of years for outmigrating winter-run Chinook salmon juveniles.	Listed Fish Performance; Yolo Bypass
Limit adult winter-run Chinook salmon passage delays in the Yolo Bypass to fewer than 36 hours and avoid false attraction into the Colusa Basin.	Yolo Bypass
Operate water facilities in a manner that does not result in a reduction in area or appreciably diminish the physical and biological features of designated critical habitat for winter-run Chinook salmon within the Action Area.	Listed Fish Performance; Riparian, Channel Margin & Floodplain Restoration
Operate water facilities to support a wide range of life-history strategies for winter-run Chinook salmon without favoring any one life-history strategy or trait over another (e.g., real-time operation of water facilities will have an implementation window covering at least 95% of the life stages present in the Action Area).	Listed Fish Performance

Chinook Salmon, Central Valley Spring-Run Evolutionarily Significant Unit	
For spring-run Chinook salmon originating in the Sacramento River and its tributaries, achieve through the CWF and other actions an interim 5-year geometric mean through-Delta survival objective of 50% (up from an estimated 40%) as measured between Knights Landing and Chipps Island. The Sacramento River survival metric is an interim value based on limited data from fall-run Chinook salmon in the Sacramento River. This survival metric will be revised to account for new monitoring data and improved modeling when available. For spring-run Chinook salmon originating in the San Joaquin River and its tributaries, achieve through the CWF and other actions an interim 5-year geometric mean through-Delta survival objective of 33% as measured between Mossdale and Chipps Island.	Listed Fish Performance
Create a viable alternate migratory path through Yolo Bypass in >70% of years for out-migrating spring-run Chinook salmon juveniles.	Yolo Bypass
Operate water facilities in a manner that does not result in a reduction in area or appreciably diminish the physical and biological features of designated critical habitat for spring-run Chinook salmon within the Action Area.	Listed Fish Performance; Riparian, Channel Margin & Floodplain Restoration
Operate water facilities to support a wide range of life-history strategies for spring-run Chinook salmon without favoring any one life-history strategy or trait over another (e.g., real-time operation of water facilities will have an implementation window covering at least 95% of the life stages present in the Action Area).	Listed Fish Performance
Steelhead, California Central Valley Distinct Population Segment	
For steelhead originating in the San Joaquin River and its tributaries, achieve through the CWF and other actions an interim 5-year geometric mean through-Delta survival objective of 44% (increased from an estimated 10%) as measured between Mossdale and Chipps Island. For steelhead originating in the Sacramento River and its tributaries, achieve through CWF and other actions a 5-year geometric mean interim through-Delta survival objective of 54% (increased from an estimated 45%) as measured between Knights Landing and Chipps Island. These survival metrics are interim values based on limited data from fall-run Chinook salmon in the San Joaquin and Sacramento Rivers. These survival metrics will be revised to account for new monitoring data and improved modeling when available.	Listed Fish Performance
Create a viable alternate migratory path through Yolo Bypass in >70% of years for outmigrating steelhead juveniles.	Listed Fish Performance; Yolo Bypass

Limit adult steelhead passage delays in the Yolo Bypass and at other human-made barriers and impediments in the Action Area (e.g., Stockton Deep Water Ship Channel) to fewer than 36 hours.	Listed Fish Performance; Yolo Bypass; Riparian, Channel Margin & Floodplain Restoration
Operate water facilities in a manner that does not result in a reduction in area or appreciably diminish the physical and biological features of designated critical habitat for steelhead within the Action Area.	Listed Fish Performance; Riparian, Channel Margin & Floodplain Restoration
Operate water facilities to support a wide range of life-history strategies for steelhead without favoring any one life-history strategy or trait over another (e.g., real-time operation of water facilities will have an implementation window covering at least 95% of the life stages present in the Action Area).	Listed Fish Performance
Green Sturgeon, Southern Distinct Population Segment	
Increase juvenile green sturgeon survival (as a proxy for juvenile abundance and population productivity) and increase adult green sturgeon survival (as a proxy for adult abundance and productivity) throughout the CWF project term.	Listed Fish Performance; Yolo Bypass; Tidal Wetland Restoration; Riparian, Channel Margin & Floodplain Restoration
Eliminate stranding of adult green sturgeon at Fremont Weir, the scour pools directly below Fremont Weir, and the Tule Pool.	Listed Fish Performance; Yolo Bypass
Improve water quality parameters and physical habitat characteristics in the Bay-Delta to increase the spatial distribution of green sturgeon in the Action Area.	Tidal Wetland Restoration

Appendix 2—Key Uncertainties and Potential Research Actions Relevant to Listed Fish Species

Key Uncertainty	Potential Research Actions
What is the relationship between proposed intake design features and expected intake performance relative to minimization of entrainment and impingement risks?	Develop physical hydraulic model(s) to optimize hydraulics and sediment transport at selected diversion sites (same as preconstruction study 1, Site Locations Lab Study [Fish Facilities Working Team 2013]). 10 months to perform study; needed prior to final design.
What tidal effects and withdrawals on flow conditions occur at screening locations?	Develop site-specific numerical studies (mathematical models) to characterize the tidal and river hydraulics and the interaction with the intakes under all proposed design operating conditions (same as preconstruction study 2, Site Locations Numerical Study [Fish Facility Working Team 2013]). 8 months to perform study; needed prior to final design.
What is the optimal design of refugia areas (macro, micro, and base refugia)?	Test and optimize the final recommendations for refugia that will be required for installation at the north Delta diversion facilities (same as preconstruction study 3, Refugia Lab Study [Fish Facility Working Team 2013]). 9 months to perform study; needed prior to final design.
How does refugia function at future fish screens?	Evaluate the effectiveness of using refugia as part of diversion structure design for the purpose of providing areas for juvenile fish passing the screen to hold and recover from swimming fatigue and to avoid exposure to predatory fish. In addition, gain insights (through observation) into the biological benefits of incorporating refugia into diversion structures (same as preconstruction study 4, Refugia Field Study [Fish Facility Working Team 2013]). 2 years to perform study; needed prior to final design.
How does water velocity distribution at river transects within the proposed intake reaches vary under differing river flow conditions?	Characterize the water velocity distribution at river transects. Water velocity modeling in the Sacramento River will identify how NDDs affect hydraulics in conjunction with changes in flow rate and tidal cycle (same as preconstruction study 7, Flow Profiling Field Study [Fish Facility Working Team 2013]). 1 year to perform study; needed prior to final design.
What are the effects of deep-water screens	Use a computational fluid dynamics model to

Key Uncertainty	Potential Research Actions
on hydraulic performance?	identify the hydraulic characteristics of deep water fish screen panels (same as preconstruction study 8, Deep Water Screens Study [Fish Facility Working Team 2013]). 9 months to perform study; needed prior to final design.
How will the new north Delta intakes affect survival of juvenile salmonids in the affected reach of the Sacramento River?	Determine baseline rates of survival for juvenile Chinook salmon and steelhead within the Sacramento River in the vicinity of proposed north Delta diversion sites for comparison to post-project survival in the same area, with sufficient statistical power to detect a 5 percent difference in survival. Following initiation of project operations, continue studies using same methodology and same locations. Identify changes in survival rates due to construction/operation of the intakes (same as preconstruction study 10, Reach-Specific Baseline Juvenile Salmonid Survival Rates, and post construction study 10, Post-Construction Juvenile Salmon Survival Rates [Fish Facilities Technical Team 2011; Fish Facility Working Team 2013]). The preconstruction study will require at least 3 years, and must be completed before construction begins. Post construction study to cover at least 3 years, with sampling during varied river flows and diversion rates.
Where is predation likely to occur in the vicinity of the new North Delta intakes?	Perform field evaluation of similar facilities (e.g., Freeport, RD108, Sutter Mutual, Patterson Irrigation District, and Glenn Colusa Irrigation District) and identify predator habitat areas at those facilities (same as FFTT preconstruction study 5, Predator Habitat Locations). This 1 or 2 year study is needed prior to intake facility final design.
What is the density and distribution of predators in the intake reach of the Sacramento River?	Use a Didson camera or other technology and/or acoustic telemetry at two to three proposed screen locations; perform velocity evaluation of eddy zones if needed. Collect baseline predator density and location data prior to facility operations; compare to density and location of predators near operational facility. Identify ways to reduce predation at the facilities (same as FFTT study 9. Predator Density and Distribution, both pre- and post-construction). These studies should be started as soon as possible to collect multiple annual datasets before construction begins. The studies should continue 3

Key Uncertainty	Potential Research Actions
	years post construction (provided varied river flows and sufficient predator populations).
What are the best predator reduction techniques? Which are feasible, most effective, and best minimize potential impacts on listed species?	Perform literature search and potentially field evaluations at similar facilities (e.g., Freeport, RD108, Sutter Mutual, Patterson Irrigation District, and Glenn Colusa Irrigation District). Test and evaluate various predator reduction techniques at operational south Delta facilities with regards to efficacy, logistics, feasibility, cost and benefits, and public acceptance. Determine if these techniques also take listed fishes and assess ways to reduce such by-catch, if necessary (extended version of FFTT Pre-construction study 6, Predator Reduction Methods). This 2 year study must be completed prior to final design of north Delta intakes.
How do reductions in south Delta exports and presence of the operable gate at the head of Old River, together with other conservation measures, influence through-Delta survival of San Joaquin River region juvenile salmonids?	Assess survival using acoustically tagged juvenile salmonids, employing methods similar to those of Buchanan et al. (2013). Overall through-Delta survival, together with reach-specific (e.g., head of Old River to Middle River) and pathway-specific (e.g., Chipps Island via Old River) survival, would be used to assess the importance of CWF operations as well as the effectiveness of other mitigation measures. Predation near the proposed head of Old River barrier (at and near the operable gate) would be studied with a multi-receiver hydroacoustic array. Conduct 3-5 years of study prior to CWF implementation in order to capture years with varying hydrology; another 3-5 years of study is needed after CWF implementation.
What are the effects of localized predator reduction measures on predator fish and listed fish species?	Use before and after studies to evaluate the distribution and abundance of predators and listed fish species at treatment location and nearby sites. Metrics include abundance, age classes, and distribution of predators such as striped bass, largemouth bass, and other smaller piscivorous fish. Measure rates of site recolonization by predators following reduction treatments. This 2- to 3-year study should be performed by year 5 of CWF implementation.
Under what circumstances and to what degree does predation limit the productivity of listed fish species?	Evaluate predation effect on productivity of listed fish species using life-cycle simulation models and site-specific bioenergetics modeling (Loboschefsky et al. 2012). This would be a 1-year study, best

Key Uncertainty	Potential Research Actions
	performed after other studies (listed above) investigating the overall incidence of predation.
How should hotspots for localized predator reduction and/or habitat treatment be prioritized?	Document the extent and locations of predator hotspots within the Delta, and evaluate relative intensity of predation and feasibility of treatment. Use a habitat suitability approach at known hotspots to identify specific physical features and hydrodynamic conditions that facilitate elevated predation loss. Perform tagging studies to identify areas that facilitate intense predation (e.g., Bowen et al. 2009; Vogel 2011). This 1-year study, should be performed by year 5 of CWF implementation.
Which predator species and life stages have the greatest potential impact on listed fish species?	Determine whether large predators that are comparatively easy to target for reduction are the key predators of some or many listed fishes. Conduct site-specific monitoring of predator abundance (by species and life stage) during periods when listed fish species (particularly juvenile salmonids) are present. Determine site-specific diet composition of predators (e.g., using DNA analysis of predator stomach contents). This 1- to 3-year study should be performed by year 5 of CWF implementation.
Is modification of sportfishing regulations a viable and effective means of achieving localized predator reduction?	Perform literature review and interviews with qualified agency and independent scientists to summarize potential benefits, hazards, costs, and implementation issues associated with using modification of sportfishing regulations to manage predatory fish in the Delta. This up-to-1-year study should be performed by year 5.
How have other actions implemented as part of the current BiOps, CWF mitigation, and EcoRestore affected the distribution and intensity of predation in the Action Area?	Restoration actions are expected to create additional habitat for some species of predators along with listed species (e.g. Yolo Bypass Fisheries Enhancement, Tidal habitat Restoration, Seasonally Inundated Floodplain Restoration, Channel Margin Enhancement, and Riparian Natural Community Restoration). Monitoring and potential active adaptive management studies will be developed, if increased predation is suspected or demonstrated in conjunction with habitat restoration or enhancement projects. Study timing and duration to be determined by CAMT; studies performed periodically during ongoing implementation the current BiOps, EcoRestore and CWF.

Key Uncertainty	Potential Research Actions
How effective are nonphysical barriers at keeping salmonid fishes in desired channels over the long term?	Multiple studies can inform this question, including (1) evaluate change in distribution, abundance and survivorship of listed species in barrier vicinity; (2) evaluate listed species behavioral response to barriers; (3) evaluate effectiveness of barriers in high-flow areas and reversing-flow areas; and (4) evaluate the barrier performance with studies using tagged juvenile salmonids.
How do nonphysical barriers affect predators?	Determine the abundance of predators, by species, within the area of the nonphysical barriers, both before and after installation, and evaluate the effect of the barriers on the survival of out-migrating juvenile salmonids. Determine whether predators are attracted to the nonphysical barriers, and if so, the locations relative to the barrier where they aggregate, and how they respond to changes in barrier operation.
Do nonphysical barriers delay upstream-migrating adult salmonids and sturgeons?	Evaluate the behavior of upstream-migrating adult salmonids and sturgeons at nonphysical barriers, for evidence of delay caused by the barriers. Viable methods may include conducting DIDSON monitoring, or by acoustic tagging.
Improve understanding of the relationship between flow regimes and year class recruitment for green sturgeon	Reanalysis of existing year-class strength data (e.g., from Fish [2010], with updates for additional years), with model selection of various potential explanatory flow variables (e.g., flows within the Action Area) in order to test clearly defined hypotheses (e.g., winter flows are important to migrating adults to stimulate upstream migration and gonadal maturation; Fish 2010). Possible field studies involving acoustically tagged sturgeon in the Action Area to assess the importance of Delta outflow on adult and juvenile migration success. Completion prior to initial operations of north Delta diversions, if possible, with additional study following implementation of CWF
To what extent does the CWF reduce straying of adult San Joaquin River region fall-run Chinook salmon?	Following the suggestions of Marston et al. (2012: 19), assess the influence on straying rate (as measured by coded wire tag returns) of 1) relative roles of south Delta exports and San Joaquin River flow, 2) the timing of pulse flows and export reductions, and 3) the role of pulse flows versus base flows. Changes in these factors and stray rate following implementation CWF would be examined,

Key Uncertainty	Potential Research Actions
	in addition to changes in total escapement. For field study, 3-5 years of study prior to CWF implementation in order to capture years with different varying hydrology; 3-5 years of study after CWF implementation.
Do lower attraction flows below the north Delta intakes result in greater straying of upstream migrating adult anadromous fishes from the Sacramento River region?	Capture and acoustically tag adult salmonids and sturgeons in San Francisco Bay or Suisun Bay, then track movement using existing hydroacoustic array. Assess proportion entering non-natal river region, then relate this to flow experienced during migration period. As an alternative or in addition, a study of existing coded-wire tag data from recovered carcasses could be done, in a similar manner to that of Marston et al. (2012), in order to assess the rate of straying in relation to flows during upstream migration. 3-5 years of study required prior to CWF implementation; another 3-5 years of study following CWF and EcoRestore tidal habitat restoration implementation; the actual number of years will be dependent on hydrology encountered and schedule of restoration.
How do north Delta intake bypass flows, Delta Cross Channel gate operations, and tidal habitat restoration in Cache Slough influence listed fish (primarily juvenile salmonid) movement into and survival in the interior Delta due to entry through Georgiana Slough and the Delta Cross Channel?	Conduct modeling including CWF operations and proposed tidal habitat restoration site designs to assess hydrodynamics in Action Area channels. Using acoustic tag studies, assess fish survival and movement in the Action Area, particularly at the Sacramento River-Georgiana Slough junction (would be studied as part of CWF6 assessment). Use flow data from existing gauges to derive Sacramento River inflow relationships with the flow split at the Sacramento River-Georgiana Slough divergence before and after implementation of CWF and tidal habitat restoration. 3-5 years of study prior to CWF implementation; 3-5 years of study following CWF and tidal habitat restoration implementation; number of years dependent on hydrology encountered and schedule of restoration.
To what extent does CWF change the abundance and distribution of Microcystis?	Assess abundance and distribution of Microcystis using field studies such as those of Lehman et al. (2005, 2010). Study to be performed during summer months following implementation of CWF (i.e., after north Delta intakes are completed and diversions at the south Delta export facilities decrease). Multiple year study to capture

Key Uncertainty	Potential Research Actions
	hydrological and operational variability.
How do CWF, BiOp and EcoRestore implementation alter suspended sediment concentrations and water clarity in the Delta?	Develop a suspended sediment model that includes representation of potential areas of tidal restoration and areas of flow alteration due to CWF water operations. Apply this model to develop and adapt sediment management actions, e.g., by modeling alternative locations for release of reusable tunnel material and sediment removed by the north Delta intakes, in order to maximize the potential for beneficial effects on suspended sediment in the Delta.

Appendix 3—Key Uncertainties and Potential Research Actions Relevant to the 2009 NMFS Operations Biop RPA Elements for Yolo Bypass

Key Uncertainty	Potential Research Actions
How effective are the fish passage modifications at Fremont Weir?	Evaluate the effectiveness of the fish passage gates at Fremont Weir and the effectiveness of the sturgeon ramps.
How effective are the fish passage modifications at Sacramento Weir?	Determine whether Sacramento Weir improvements have benefited fish passage and minimized stranding risk.
How effective are the fish passage modifications within the Yolo Bypass itself?	Determine whether stilling basin modification has reduced stranding risk for listed fishes. Determine effectiveness of Tule Canal/Toe Drain and Lisbon Weir improvements in reducing the delay, stranding, and loss of migrating salmon, steelhead, and sturgeon.
Have the Lower Putah Creek enhancements had the expected effects on fish passage?	Evaluate whether the Lower Putah Creek realignment has improved upstream and downstream passage of listed fish.
Is the modified inundation regime affecting predation on listed fishes in the Bypass?	Determine severity of predation effects on listed fish that use the Yolo Bypass.
Is the modified inundation regime improving production of forage for listed fishes?	Determine plankton and invertebrate production rates during periods of Fremont Weir operation.
Is the change in foraging resources producing improved growth rates among rearing salmonids?	Determine growth rates of juvenile salmonids that have entered the Yolo Bypass during Fremont Weir operation.
What proportion of upstream migrating adult salmonids and sturgeons enter the Yolo Bypass and may be subject to delay at passage barriers?	Capture and acoustically tag adult salmonids and sturgeons in San Francisco Bay or Suisun Bay, then track movement using existing hydroacoustic array, augmented as necessary with new hydrophones in the Yolo Bypass area. Assess use of different routes through the Yolo Bypass and Delta to upstream spawning areas. Study should include collection of 3-5 years of data prior to implementation of Yolo Bypass passage improvement projects in order to capture years with varying hydrology (including overtopping and no overtopping of Fremont Weir), and an additional 3-5 years of data collection after passage improvement projects have been implemented.

Appendix 4–Key Uncertainties and Potential Research Actions Relevant to Tidal Wetland Restoration

Key Uncertainty	Potential Research Actions
How does tidal marsh restoration affect production of food suitable for listed fish species both within and outside of the restored sites?	Quantify primary and secondary production, including food suitable for listed species, both within restored tidal marsh natural communities and transported from restored areas to adjacent open-water habitat and the fate of that production.
How have hydrodynamic changes associated with tidal restoration affected organic carbon transport and fate?	Quantify the flux of organic carbon produced in restored tidal marsh plain into existing channels in the Action Area.
How has tidal marsh restoration affected benthic invertebrate communities? In particular, how are invasive mollusks affecting zooplankton production in restored tidelands?	Document and evaluate water quality conditions in restored subtidal aquatic habitats. Assess density and foraging effectiveness of Asian clams or other invasive species that colonize restoration sites. Periodically repeat surveys to determine if delayed colonization occurs.
What is the relationship between life cycles of listed fish and those of invasive mollusks?	Identify constraints limiting larval transport, settlement and establishment of invasive mollusks; the role of nutrients in facilitating invasion; and potential control mechanisms for invasive mollusks.
To what extent does intertidal wetland restoration result in changes in contaminants that could affect listed fishes?	Compare contaminant concentrations at representative sites in/near restored areas before and after restoration has occurred. Must occur prior to restoration, and following restoration, with sufficient sampling intensity over a variety of hydrological conditions to allow inferences to be made about a range of water-year types.
How effectively do minimization measures limit production and mobilization of methylmercury from tidal restoration sites and the food web?	A connected group of studies will be needed, likely at a representative selection of restoration sites. Studies will evaluate wetland management strategies intended to minimize methylation, evaluate the ecological fate of wetland-generated methylmercury, evaluate the biological thresholds for mercury exposure for listed species to guide methylmercury objectives and Delta wetland management priorities, and evaluate the effectiveness of site screening.

Key Uncertainty	Potential Research Actions
What are the most effective designs of tidal restoration sites to achieve tidal flow velocities that preclude rooting by invasive aquatic vegetation (IAV)?	Resolution of this question requires conducting a linked series of studies: (1) empirical and lab studies to determine flow constraints on rooting of IAV species of concern, (2) model studies to assess velocity field for alternative restoration site design, and (3) field tests in restoration site projects.
How are restored natural communities being affected by IAV and have there been changes in existing areas of IAV presence?	Evaluate the effect of tidal restoration on the establishment of IAV in subtidal aquatic habitats. Evaluate whether or not there have been changes in the abundance and distribution of IAV that could be related to the Action (e.g., changes in Delta hydrodynamics).
Is it feasible to create conditions that favor the growth of native pondweeds (*Stuckenia* spp.) rather than IAV?	Various approaches exist to address this topic, potential ones include (1) evaluate environmental conditions that support native pondweed stands, focusing on abiotic factors (particularly salinity) that determine growth and distribution of native pondweeds, (2) evaluate how future salinity changes affect growth and distribution of pondweeds and *Egeria*; (3) determine environmental conditions and abiotic factors that favor *Stuckenia* over *Egeria*, (4) evaluate to what extent restoration sites can be designed to encourage colonization and growth of native pondweeds while discouraging *Egeria*, (5) determine the potential for native pondweed stands to contribute to restoration of native communities and ecosystem functions in the Delta, and (6) determine if the epifaunal invertebrate assemblages supported by native pondweed stands provide substantial foraging and cover benefits in comparison with *Egeria*.
Do juvenile sturgeon use restored tidal wetlands?	Capture and acoustically tag juvenile sturgeons in Action Area, then track movement using existing hydroacoustic array. Assess fraction of time in or adjacent to restored tidal wetlands. Begin the 3-5 year-long study when 20% of the tidal wetland restoration acreage is achieved.

Appendix 5–Key Uncertainties and Potential Research Actions Relevant to Channel Margin Restoration

Key Uncertainty	Potential Research Actions
How is predation affecting listed fishes in restored channel margin habitat?	Quantify abundance of nonnative fishes in restored channel margins. Assess effects of nonnative fish predation on listed species in restored sites. Identify ways to avoid and minimize those impacts.
Does channel margin enhancement contribute to an increase in survival of fry-sized Chinook salmon in restored river reaches?	At representative channel margin enhancement sites, mark and recapture fry-sized Chinook salmon. This work should include collection of 3-5 years of data before implementation at the site in order to establish a baseline condition capturing years with varying hydrology and an additional 3-5 years of data collection after the channel margin enhancement has been constructed.
How frequently are channel margins enhanced under the CWF inundated and how frequently are existing riparian and wetland benches inundated? How do these frequencies change as a result of the CWF?	Develop, in collaboration with USFWS, NMFS and DFW, a study to more precisely define this uncertainty and resolve it using a combination of modeling and field data collection.

Appendix 6–Delta Outflow

The Outflow Focus areas are a structured element that will assist in determining initial flow criteria for CWF. Any revisions to the operating criteria would be enacted according to the adaptive management process described in this Framework. There are three outflow focus areas; two address summer and fall outflow and their importance to Delta Smelt and the other addresses spring outflow and its importance to longfin and Delta Smelt. (See the December 2013 public draft of BDCP Section 5.5.1.1.2, *Fall X2 Outflow Process*, for an explanation of the importance of the fall outflow to Delta Smelt, the potential outcomes associated with each branch of the fall outflow topic, and the prevailing sources of uncertainty in those outcomes. The December 2013 public draft of BDCP Section 5.5.2.1.1, *Spring Outflow Process,* provides the corresponding discussion for longfin smelt.)

Fall X2

Resolution of the fall X2 questions requires ascertaining Delta Smelt's fall outflow needs to determine what is needed to avoid jeopardy and adverse modification to Delta Smelt critical habitat. The fundamental premise is that Delta Smelt abundance can be improved by providing fall outflow consistent with the current RPA.

Resolution of the fall X2 questions requires the following process:

1. Convert existing conceptual models to a spatially explicit numeric model using studies that calibrate transitions between life stages within the conceptual model (Newman life-cycle model, USFWS in development).
2. Develop a numerical model based on Bever et al. (2016) to evaluate a range of scenarios that use various outflow values and various configurations of tidal restoration to describe flow-habitat equivalency.

The conceptual model for Delta Smelt performance is based upon the habitat metrics presented in the objective in Appendix 1—Initial Objectives Derived From Current Biops/CESA and CWF), which states:

Provide a monthly average of at least 37,000 acres of open-water habitat in hydrologically wet years, and at least 20,000 acres of connected open-water habitat in hydrologically above-normal years, of habitat surface area during July–November that is between 1-6 psu. This habitat will additionally meet all of the following criteria: extensive vertical circulation including gravitational circulation, contiguous with other open-water habitat, lateral mixing, and other hydrodynamic processes keeping Secchi disk depths less than 0.5 meters, high calanoid copepod densities (over 7,000 per cubic meter), hydrologically connected to substantial tidal marsh areas, and maximum water temperatures less than 25°C.

The habitat criteria dealing with hydrodynamics are intended to ensure sufficient turbulence to maintain water turbidity and thereby attain compliance with the Secchi disk criterion, so the criteria expressed in this objective become salinity, Secchi disk depth, calanoid copepod density, proximity to tidal marsh, and water temperature. These habitat suitability criteria can be measured in a spatially explicit manner to determine the acreage of qualifying habitat available under a given set of environmental conditions.

Table 1. Key Questions and Possible Investigative Approaches to Address Fall Outflow Management

Key Questions	Possible Investigative Approaches
Are there biases in the IEP survey data? How should the survey data be utilized if biases do exist?	Convene a workshop to discuss possible survey problems and identify opportunities to address with existing data.
Under what circumstances does survival in the fall affect subsequent winter abundance?	Quantitatively determine the contribution of Delta Smelt survivorship in the fall to inter-annual population variability. Review available lifecycle models for applicability.
Under what circumstances do environmental conditions in the fall season contribute to determining the subsequent abundance of Delta Smelt?	Investigate the relationship between fall outflow and the relative change in Delta Smelt abundance using univariate and multivariate and available historic data.
How much variability in tidal, daily, weekly, and monthly fluctuations in fall X2 is attributable to water project operations?	Use hydrological modeling tools to determine the prospective locations of X2 in the fall under circumstances with and without project operations. An analysis of historical data will also be carried out to examine outflow during periods when the projects were required to meet specific outflow requirements, to evaluate the degree of control that has been possible at various time scales.
Under what circumstances is survival of Delta Smelt through the fall related to survival or growth rates in previous life stages?	Compare Delta Smelt survival during the fall to both survival in prior seasons and to fork length at the end of the summer/start of the fall. New data are being collected as part of the Fall Outflow Adaptive Management Plan (FOAMP).
Does outflow during the fall have significant effects on habitat attributes that may limit the survival and growth of Delta Smelt during the fall?	There may be competing approaches that will be simultaneously pursued. One is to develop graphs and conduct univariate and multivariate analyses involving survival ratios and growth rates. Another option is to test whether month-to-month declines in abundance or growth during the fall is greater when X2 is located further east. See also the analytical approach in MAST report, as well as work by Kimmerer, Burnham & Manly.
Can an index based on multiple habitat attributes provide a better surrogate for Delta Smelt habitat than one based only on salinity and turbidity?	Review approaches in existing literature. There may be competing approaches that will be simultaneously pursued, depending on expert advice. One possible approach is to develop suitability index curves and combine geometrically to create a habitat quality index. Data from areas where Delta Smelt are frequently observed will be utilized to assess

Key Questions	Possible Investigative Approaches
	habitat quality.
Under what conditions (e.g., distribution of the population, prey density, contaminants) do fall operations have significant effects on Delta Smelt survival?	Utilizing relationships identified in the above studies, simulate how changes in project operations may influence survival of Delta Smelt during the fall.
Source: Collaborative CAMT (2014)	

Spring Outflow

Based on the fall midwater trawl indices of longfin smelt abundance, there are significant correlations between Delta outflow during the winter-spring months and subsequent longfin smelt abundance in the fall (Rosenfield and Baxter 2007; Kimmerer et al. 2009; Baxter et al. 2010; Rosenfield 2010). Particular attention in CWF is focused on resolution of the spring outflow needs to avoid jeopardy and achieve the full mitigation standard for longfin smelt required under CESA. The fundamental premise for this is that longfin smelt performance can be improved, thereby improving Longfin Smelt abundance, by either increasing spring outflow, improving food availability by restoring tidal habitat or improving water quality (ammonium reduction), or by some combination of these changes. (See the December 2013 public draft of BDCP Section 5.5.2.1.1, *Spring Outflow Process*, for detailed explanation of the conceptual models underlying these options.) In the case of longfin smelt, it is not clear which particular months of increased outflow yield beneficial outcomes (e.g., winter vs. spring), whether increased outflow needs to be sustained or if they can be produced by pulse flows, or if increased outflow must occur in the context of other preconditioning circumstances such as availability of particular foraging resources. These uncertainties point to the need for substantial research to elucidate mechanisms whereby flow increases can benefit longfin smelt, prior to resolution of the spring outflow.

Resolution of the spring X2 questions requires research to answer the following:

- What are the mechanisms by which spring outflow is important for longfin smelt recruitment?
- What flow is required to make each mechanism work?
- What are the important sources of mortality for longfin smelt?
- Is there evidence that habitat restoration will increase longfin smelt recruitment per unit of spring outflow?
- How do different outflow operations (e.g., pulse flows vs. more continuous flow) in the spring affect longfin smelt recruitment?

Studies and Monitoring Supporting the Spring Outflow

Winter-spring outflow has remained positively correlated with the subsequent fall's abundance index of longfin smelt, despite fewer longfin smelt being produced per unit of outflow as a result of prey abundance after *Potamocorbula amurensis* invasion and even when corrected for estimated spawner abundance. A scientific understanding of what this flow correlation represents could be achieved with modeling studies. The modeling approach may facilitate the investigation of how different outflow operations (e.g., pulse vs. more continuous flow) might affect distribution and retention of young longfin smelt, should a retention mechanism be deemed of high importance.

Monitoring and research of food (i.e., zooplankton and other prey) produced within areas restored under the current BiOps and EcoRestore, and the extent to which this food is exported from these areas and consumed by longfin smelt, would be undertaken to inform the potential for habitat restoration to produce an increase in the number of longfin smelt per unit of spring outflow. Potential monitoring research actions supporting this work are described further in *Appendix 2—Key Uncertainties and Potential Research Actions Relevant to Listed Fish Species*, and ultimately would aim to quantify the fraction of longfin smelt production stemming from restored marsh areas (e.g., with studies of the isotopic signature of longfin smelt tissue in relation to the isotopic signature of marsh-derived phytoplankton and zooplankton). Resolution of the spring X2 questions then requires the following process:

1. Perform studies to better understand how longfin smelt use the Bay-Delta estuary.
2. Perform studies to better understand what habitat attributes are supporting longfin smelt performance and which ones are not.
3. Develop and calibrate a spatially explicit habitat suitability model to compare longfin smelt performance to a range of scenarios that use various outflow values and various configurations of tidal restoration to describe flow-habitat equivalency.
4. Refine quantitative life cycle models using the information from steps 1-3.

Longfin smelt distribution in the estuary could be better understood than it is presently. The current status of knowledge is summarized by Hobbs et al. (2014), who also identified a 5-year research plan incorporating a range of studies to resolve the principal remaining uncertainties (Table 1). These studies will also produce progress toward a better understanding what habitat attributes are supporting longfin smelt, but it is likely that a second round of studies, incorporating results from the work proposed by Hobbs et al. (2014), will be needed to improve that understanding to the point at which existing conceptual models are ready for transformation into revised numerical models. Further studies will likely be needed to achieve calibration and to compare flow scenarios in a manner similar to that described above for the fall X2.

Table 2. Research Questions Addressed in Longfin Smelt Study Plan of Hobbs et al. (2014)

Key Questions	Investigative Approaches
Longfin Smelt distribution and regional contribution to overall abundance	1. Do Longfin Smelt spawn in Bay tributaries? H_o : Longfin Smelt will not be found to spawn in Bay tributaries. H_a : Longfin Smelt will be found to spawn in Bay tributaries. 2. If spawning occurs in Bay tributaries, are there substantial

Key Questions	Investigative Approaches
	differences in production during wet versus dry years? H_o : The magnitude of longfin smelt production in Bay tributaries does not vary by water year type. H_a : The magnitude of longfin smelt production in Bay tributaries is substantially higher in wet years. 3. Is longfin smelt larval production in Bay tributaries sufficient to influence the abundance indices of YOY and adult (age 1+) longfin smelt captured by DFW surveys in the estuary? How does the contribution of Bay tributary spawning to year class strength vary in response to variation in hydrologic conditions (e.g., wet vs. dry years, etc.)? H_o : Larval production in Bay tributaries does not influence the abundance index of YOY and/or adult longfin smelt. H_{a1} : Larval production in Bay tributaries does influence the abundance index of YOY and adult longfin smelt. H_{a2} : The magnitude of tributary spawning and the survival of longfin smelt spawned in Bay tributaries (i.e., contribution of tributary spawning to population abundance of juveniles and adults) varies among years in response to hydrologic conditions. 4. Will Bay tributaries have unique geochemical signatures that allow identification of regional geographic areas of production (e.g., differentiate production in Bay tributaries from Sacramento and San Joaquin river production) and, under the best case scenario, have geochemical signatures that would allow differentiation of production among individual tributaries? H_o : Geochemical signatures will not differ among the Sacramento and San Joaquin rivers and Bay tributaries. H_a : Geochemical signatures will be sufficiently different to discriminate between the Sacramento and San Joaquin rivers and Bay tributaries and possibly among individual Bay tributaries. 5. If geochemical signatures are discernible among geographical areas and salinity zones, what is the relative contribution of larvae rearing in different geographical areas and salinity zones to the YOY and adult (age 1+) population? H_o: Most longfin smelt production originates from upstream areas, specifically the low salinity zone of the Sacramento and San Joaquin rivers. H_a: Bay and Bay tributary production is a major contributor to the longfin smelt population. 6. Will geochemical signatures of the Bay differ from the nearshore marine coastal waters such that fish moving into or out of San Francisco Bay could be identified? H_o : Geochemical signatures of longfin smelt in San Francisco Bay will

Key Questions	Investigative Approaches
	not differ from the nearshore coastal environment. H_a : Geochemical signatures of longfin smelt in San Francisco Bay will be significantly different from the nearshore coastal environment.
Longfin Smelt vertical migration behavior	7. Do longfin smelt undergo a diel (daily) or tidal migration in the water column? If present, does this behavior vary regionally (i.e., in central San Francisco Bay vs. Suisun Bay)? H_0: Longfin smelt do not exhibit any diel or tidal vertical migration behavior: catch in the upper part of the water column (as measured by FMWT and Bay MWT) and deeper waters (as measured by the Bay otter trawl) do not vary between night and day, or over tidal cycles. H_{a1}: Longfin smelt do exhibit diel or tidal vertical migration behavior: catch in the upper part of the water column (as measured by FMWT and Bay MWT) and deeper waters (as measured by the Bay otter trawl) varies between night and day, or over tidal cycles, or both. H_{a2}: Longfin smelt diel or tidal vertical migration behavior varies between regions of the estuary. 8. Is Longfin smelt catch affected by water transparency? H_0: Water transparency does not influence MWT or otter trawl catch of longfin smelt. H_a: Longfin smelt catch in the upper part of the water column (as measured by FMWT and Bay MWT) and deeper waters (as measured by the Bay otter trawl) varies with water transparency, with decreased catch in the upper water column at high levels of water clarity. This effect of water transparency would result in variation in the catch ratio of BWT:OT across water clarity levels.

Appendix 7−Groups Involved In Each Phase of the Adaptive Management Framework

<u>Phase 1: Plan.</u> Facilities and Operations, Restoration/Ecosystem Management, and Monitoring and Research.

- Interagency Implementation Coordination Group (IICG convened by DWR and Reclamation) (NMFS, USFWS, DFW, DWR, BOR, SWC, SLDMWA).
  - Fish Facilities Design and Evaluation Teams (current BiOps/CESA, CWF)
  - NDD Facility design and associated engineering and evaluation (CWF)
  - Screen and Bypass criteria effectiveness evaluation Team (CWF)
  - Existing South Delta fish facilities Teams (current BiOps/CESA)
- Tidal Wetland Restoration Implementation (EcoRestore, current BiOps/CESA, CWF)
  - Fish Restoration Program (FRP) and State and Federal Contractors Water Agency (SFCWA) Tidal Wetland Restoration Project design and implementation Teams (current BiOps/CESA)
  - Fisheries Agencies Strategy Team (FAST)
  - FRP Monitoring (Tidal Restoration monitoring Project Work Team)
  - CWF tidal habitat mitigation
- Yolo Bypass Fishery Enhancement Plan Design and Implementation (current BiOps/CESA)
  - Yolo Bypass Cache Slough Partnership
- Interagency Ecological Program (current BiOps/CESA, CWF, Water Quality Control Plan)
  - Monitoring and research to support SWP/CVP operations, maintain permit compliance and address emerging science questions related to the health of the Delta and listed species affected by operations.
  - Organizational structure
- Current BiOps/CESA Implementation (USFWS, DFW, NMFS, Reclamation, DWR)
  - Biannual Review of operations and implementation of the current BiOps' RPA actions for purposes of change within Adaptive Management provisions (LOBO Independent Reviews conducted by DSP)
- Collaborative Science and Adaptive Management Process (current BiOps/CESA)
- Delta Science Program/Delta Science Plan
  - Interim Science Action Agenda – Priority Science for the Delta
  - Independent Review Panels (LOBO) regarding implementation of current BiOps and CWF

- State of Bay-Delta Science
    - Host IEP Lead Scientist
- DFW Proposition 1 Delta Grants Program
- SFWCA Science Program
- Delta Regional Monitoring Program

Phase 2: Assess. Collaborative Science, Synthesis and Performance Assessment to Inform Management Direction and Change As Uncertainty Is Addressed.

- CSAMP
- Delta Stewardship Council
    - Delta Interagency Implementation Committee
- IEP Management Analysis Synthesis Team Reports (MAST, SAIL)
- LOBO reviews
- DSP Independent Reviews of CSAMP and other science products.
- Delta Independent Science Board review of Delta Science
- State of Bay Delta Science

Phase 3: Integrate. Management and Science Integration.

- Five Agencies
- CSAMP
- IICG
- DSP

Phase 4: Adapt. Process for Making Adaptive Management Changes.

- Five Agencies, based on their authorities related to SWP/CVP (current BiOps/CESA, CWF)
- SWRCB